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# Canadian Journal of Research

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## RHIZOPUS ROOT ROT OF SUGAR BEET[1]

BY A. A. HILDEBRAND[2] AND L. W. KOCH[2]

### Abstract

During the summer of 1942 sugar beets growing in an experimental plot at the Harrow laboratory were destroyed by a root rot of a type that apparently has been reported only once previously on this host in North America. Wilting of the foliage first attracts attention to affected plants, the roots of which show, externally, grayish-brown discoloured areas and, internally, fairly sharply-delimited, grayish to coffee-coloured lesions, affected tissues being more or less spongy in consistency. The causal organism, found to be a wound parasite, has been identified as *Rhizopus arrhizus* Fischer. The effect of temperature on the growth in culture and on the pathogenicity of this fungus and of representatives of the species, *R. oryzae* and *R. nigricans*, has been studied. It has been found that *R. arrhizus* and *R. oryzae* are relatively high temperature organisms, showing optimum growth at about 34° to 36° C., and each capable of infecting and destroying artificially injured sugar beets most rapidly between 30° and 40° C. *R. nigricans*, also a wound parasite is, on the other hand, a relatively low temperature organism showing optimum growth in culture at about 24° and displaying highest infection capability at about 14° to 16° C.

### Introduction

During July, 1942, a number of sugar beets growing in an experimental plot at the Harrow laboratory were attacked and destroyed by a root rot of a type that so far appears to have been reported only once previously on this host in North America. In 1915, Edson (2) described a root decay of sugar beets from California and Colorado, the symptoms of which coincide so closely with those observed more recently on the affected beets at Harrow that it seems almost certain that the same disease was concerned in these widely separated localities. From affected beets Edson isolated *Rhizopus nigricans* Ehrb. in pure culture to the extent of almost 100%. Using this organism in infection experiments Edson reproduced the disease in the laboratory on dormant beets but was unable to do so on living material in the field. From the diseased beets at Harrow a species of *Rhizopus* was isolated which, in both field and laboratory experiments, proved capable of reproducing the disease in characteristic form. Details in connection with the isolation, proof of pathogenicity, and identification of this organism, together with a study of certain of its cultural characteristics and pathogenic capabilities as compared with two other *Rhizopus* species form the content of the present paper.

[1] *Manuscript received April 20, 1943.*

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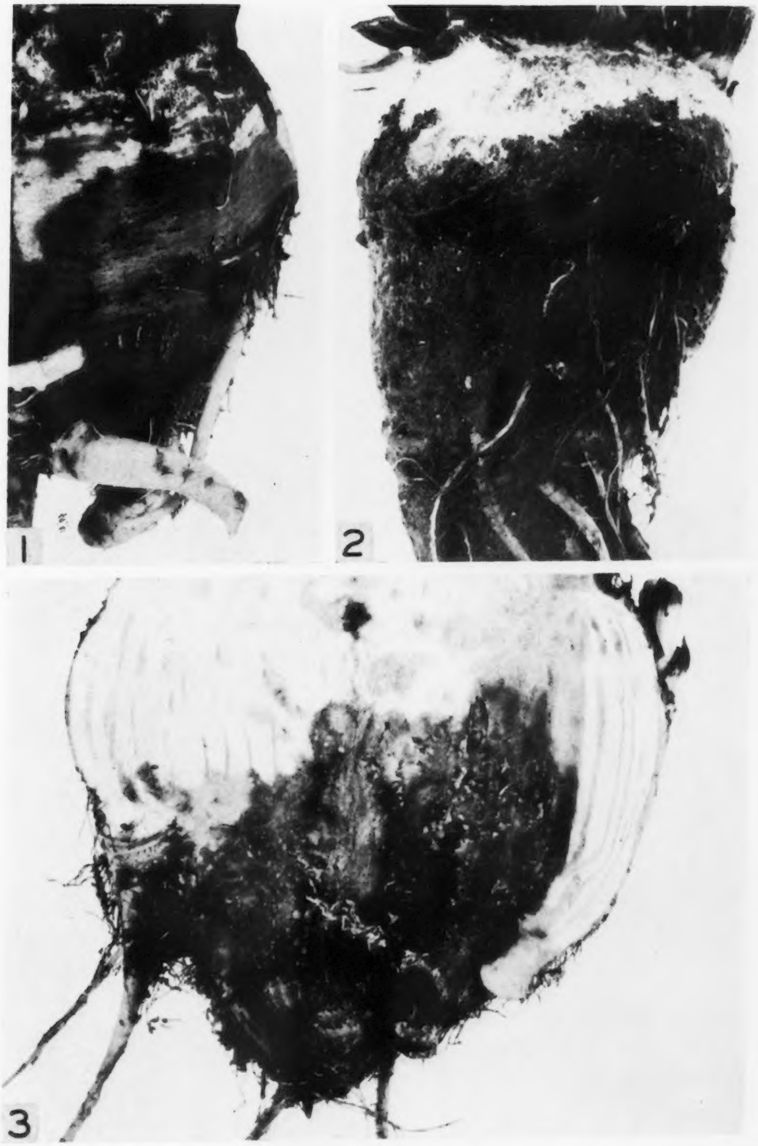
## Description of the Disease

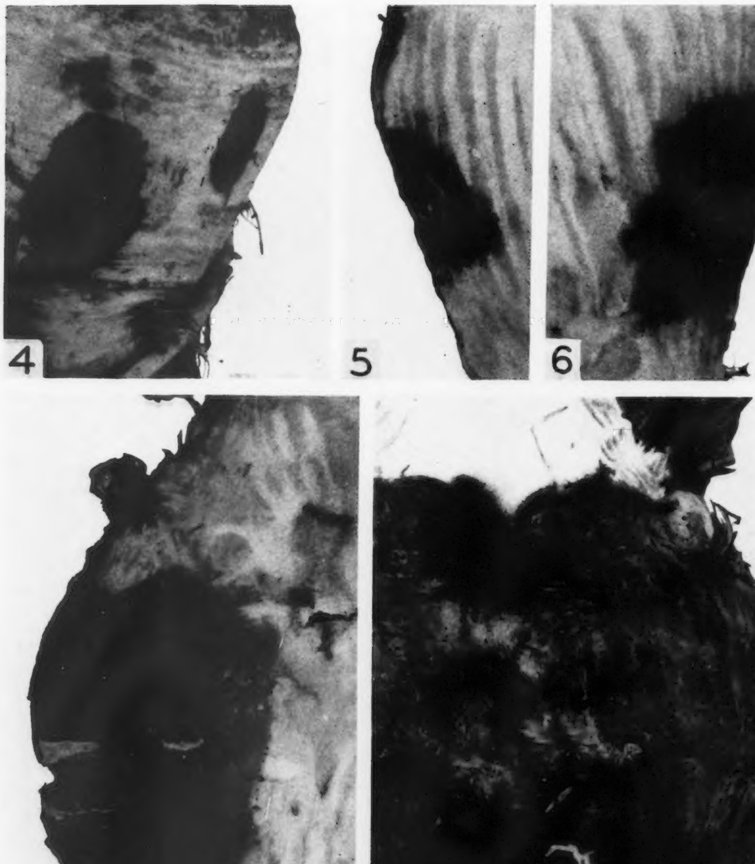
*Leaf Symptoms.*—On July 10 the first suggestion of possible trouble in the experimental planting was noted when, towards midday, the leaves of three plants were observed to be in a noticeably flaccid condition. By evening, however, the wilted foliage had made considerable recovery. During the next few days, this sequence was repeated but each day wilting at midday became more pronounced and recovery towards evening less and less apparent. By July 16 wilting of the three originally observed plants had reached the permanent stage, the crown of each being surrounded by a rosette of recumbent leaves, which, soon drying out completely, became brittle and brown. Meanwhile other plants in the plot began to show an exactly similar symptom-picture. Altogether from July 10 until September 9, 22 plants representing 12% of the total population of the plot, became affected and died. No stunting, distortion in shape, or change in colour accompanied the wilting of the leaves of affected plants.

*Root Symptoms.*—The appearance of a root affected with rot depends on the stage of development of the disease. In the early stages of infection a grayish-brown discoloured area, which indicates the presence of a lesion, appears on the surface of the tap root, more usually towards its base. If the root is cut across through such an area, the lesion is found to be quite shallow. Lesions increase rapidly in surface extent, the direction of spread seeming to be upwards towards the crown of the root (Fig. 1). Increasing external spread of the disease is accompanied by deeper penetration of the internal tissues (Fig. 3). Diseased tissue, grayish to coffee-coloured, is more or less spongy in consistency. Both externally and internally there is a fairly sharp line of demarcation between diseased and healthy tissue (Figs. 1 and 3; Figs. 4, 6, 7, and 8). Sometimes, however, vascular tissue beyond the limits of the actual lesion may appear darker than normal. An odour strongly suggestive of acetic acid emanates from freshly exposed diseased tissue. Infection progresses until finally the whole of the main tap root becomes affected and, externally, the colour of the latter changes from grayish-brown to almost black. At this stage it has been found that the soil clings so tenaciously to the diseased surface of the root that it can be removed only with difficulty. On four roots in late stages of infection, a mantle of coarse, white fungous mycelium was found enveloping the "shoulder" of the root (Fig. 2). For some time after a root has become completely affected, there may be no external change in its contour. Internally, however, cavities filled with a nearly colourless fluid apparently rich in acetic or some closely allied organic acid, may often be noted in the spongy tissue (Fig. 8). Frequently it was observed that secondary roots originating from the base of the main tap root, and penetrating the soil more deeply, remained almost unaffected by the disease.




*Roots naturally infected with R. arrhizus.* FIG. 1. *Affected root showing external appearance of lesion.* FIG. 2. *Late stage of disease showing white mantle of mycelium enveloping "shoulder" of root.* FIG. 3. *Median longitudinal section through root showing internal appearance of lesion. All about 3/4.*

PLATE II




*Artificially infected roots.* FIG. 4. *External appearance of root one week after being artificially injured and inoculated with R. arrhizus (left) and with Fusarium sp. (right).* FIGS. 5 AND 6. *Sections through root shown in Fig. 4, showing internal appearance of week-old lesions caused by Fusarium sp. and by R. arrhizus, respectively.* FIGS. 7 AND 8. *Median longitudinal sections through roots, showing progress of infection by R. arrhizus after two, and four weeks, respectively. All about 3/4.*

## Isolations from Diseased Roots

During the six-week period from July 16 until Aug. 27, 1942, isolations were made from 12 different roots showing various stages of the disease. Infected roots after being thoroughly washed were split open and from the inner extremity of freshly exposed lesions bits of tissue were transferred to poured plates of potato dextrose agar. Twenty such plantings (4 per plate) were made from each root, 12 to non-acidified agar and 8 to agar acidified to the extent of two drops of 25% lactic acid per 15 ml. of medium.

Of the total of 240 tissue plantings from the 12 different roots, 212 yielded cultures of *Rhizopus*, 9 produced cultures of *Fusarium*, 11 developed bacteria, and 8 failed to produce organisms of any kind. Except for the presence of bacteria in a few cultures, most of the colonies of *Rhizopus* that developed in the plates were pure and appeared to be identical. However, pure cultures of both *Rhizopus* and *Fusarium* were obtained by the monospore method.

## Infection Experiments

### A. Outdoor Experiments on Living Plants under Natural Growing Conditions

Using 6- and 12-day-old cultures of *Rhizopus* and *Fusarium*, respectively, infection experiments involving 80 healthy plants growing in an adjoining experimental plot were carried out July 28 and 29, 1942. Sufficient soil was removed from the side of a root *in situ* to expose a surface of from 6 to 9 sq. in. The surface thus exposed was brushed free of extraneous soil, further cleansed by swabbing with mercuric chloride (1:1000), and then rinsed with sterile water. Inoculum was applied both to uninjured root surfaces and to artificial wounds, three different types of which were made as follows.

(1) By means of a cork borer ($\frac{1}{2}$ in. in diameter), a plug of tissue about $\frac{1}{2}$ in. deep was removed from the root, inoculum inserted, and the plug replaced.

(2) Using a scalpel, a wedge-shaped piece of root (about $1 \times \frac{1}{4} \times \frac{1}{4}$ in.) was removed and inoculum inserted in its place.

(3) With the point of a scalpel, 12 punctures were made within a small circular area over which inoculum was applied.

The inoculated area was covered with a pad of moistened cotton before the soil was replaced around the root. Altogether 48 inoculations employing *Rhizopus* were made, numbers and treatments of roots involved being as follows: 12, cork-borer injury; 12, wedge excision; 12, scalpel punctures and 12, no artificial injury. Using *Fusarium* as inoculum an exactly similar series was completed. Eight roots were inoculated with both organisms *Rhizopus* being applied at least 2 in. distant from the point at which *Fusarium* was applied. Sixteen roots served as checks, these being accorded treatments exactly similar to those given the others, except that sterile agar replaced fungous inoculum. At weekly intervals roots were removed from the soil for examination.

*Results*

*(a) Rhizopus*

In all 24 cases involving cork-borer or wedge-excision types of injury, typical rotting of roots resulted. Just a week following inoculation, a lesion of considerable size had developed about the point of injury. At the end of two weeks the lesion had more than doubled in surface extent and in depth of penetration of the root tissues. By the end of four weeks roots were almost completely rotted. The progress of the disease as thus described is clearly shown in Figs. 6, 7, and 8. The organism was repeatedly recovered on isolation to the extent of practically 100%.

When inoculum was applied to the scalpel-puncture type of wound or to the uninjured root surface, slight infection was noted on only two of the 24 roots involved.

*(b) Fusarium*

*Fusarium* failed to produce other than slight infection and that, only when the cork-borer type of injury was employed (Figs. 4 and 5).

*(c) Checks*

All check plants, whether injured or uninjured, remained entirely free from the disease.

The results as described above would indicate quite clearly that the *Rhizopus* isolate obtained originally in such a high percentage of cases from naturally infected roots must be considered an important wound parasite possessing high pathogenic capability.

### B. Greenhouse Experiment with Seedlings

In sugar beet pathology examples are not lacking of organisms that not only attack older plants in the field but that also bear causal relationship to diseases of seedlings. Thus, *Phoma Betae* and *Rhizoctonia Solani* which, respectively, cause an important leaf spot and root rot of older beets, are both regarded as causal agents of black root of seedlings. In view of this fact it was considered that the *Rhizopus* which, as shown above, possessed such high pathogenic capability as regards older beets, might also be capable of attacking seedlings. In this connection it is to be noted that Hodges (6) includes *Rhizopus nigricans* in a group of fungi that were found to be parasitic on sugar beet seedlings in the laboratory.

On November 18, 1942, three flats of greenhouse compost soil were sterilized with steam. Three days later to the soil of one of the flats was added a quantity of crushed oats upon which the *Rhizopus* under test had been grown for six days. With the soil of the second flat was incorporated a corresponding quantity of sterilized oats, while to the soil of the third flat nothing was added. On November 25, 120 sugar beet 'seeds' of known high germinability, which had been standardized as to size by screening (16/64 — 14/64 in.) and surface sterilized by immersion in mercuric chloride (1:1000) were planted in each of the flats. The latter were watered as required and remained under close

observation in the greenhouse for 28 days. Data recorded during that period are summarized in Table I.

TABLE I

EFFECT OF ADDITIONS TO STERILIZED SOIL, OF *Rhizopus* AND OF STERILE OAT-CULTURE MEDIUM, ON GERMINATION AND INCIDENCE OF DISEASE IN SUGAR BEETS

| Additions to sterilized soil | No. 'seeds' planted | No. seedlings emerging | Percentage germination | Incidence of post-emergent disease |
|---|---|---|---|---|
| *Rhizopus* + oat-culture medium | 120 | 163 | 135.8 | 0 |
| Sterile oat-culture medium | 120 | 190 | 158.3 | 0 |
| Nil | 120 | 252 | 210.0 | 0 |

As reference to Table I will show germination was highest in the sterilized soil to which no addition was made, intermediate in that with which was incorporated sterile, oat-culture medium and lowest in that to which *Rhizopus* growing on oat-culture medium was added. Often, in experiments similar to the above, differences in emergence of seedlings are attributable in part, at least, to pre-emergent damping-off. Almost invariably, however, when damping-off is a factor, it is operative in both a pre-emergent and a postemergent phase. In the present experiment, no disease appeared after the seedlings had emerged. Thus, it would seem that factors other than those strictly pathological were responsible for the differences in seedling emergence recorded above. Apart from being fewer in number, the seedlings that grew in the soil to which *Rhizopus* was added, were as healthy and exhibited as great vigour of growth as those that developed in the non-treated, sterilized soil.

## Description of Causal Organism

Portions of infected sugar beets kept in a moist chamber soon develop an abundance of white, cottony mycelium as do also tube and plate cultures of the fungus grown at room temperature on standard potato dextrose agar. Later, following profuse formation of sporangia, the mycelial mat becomes predominantly gray in colour, with a suggestion of brown, however, as the sporangiophores change to this colour. On potato dextrose agar, aerial growth of the fungus consists of vegetative mycelium as well as of creeping filaments or stolons that show differentiation into nodes and internodes. Usually both sporangiophores and rhizoids develop at the nodes. In general, the rhizoids are poorly developed, being only slightly branched. They are yellow-brown in colour. Occasionally, rhizoids occur without sporangiophores at indefinite points along the stolons and, conversely, sporangiophores originate without rhizoids at slight swellings on the stolons, especially where the latter are remote from the substratum. The sporangiophores occur mostly singly or in small clusters of from two to three, and vary in length from 0.4 to 2 mm. At first silvery gray in colour they later become light brown. They may be

straight, obliquely slanted, curved, or almost recumbent and often show vesicular swellings. Occasionally, a sporangiophore is branched towards its tip, each branch finally bearing a sporangium. Thus is formed an umbel- or corymb-shaped group of the latter organisms. The sporangia, at first white, later blackish-brown, are spherical in shape and vary in size from 70 to 250 $\mu$. The columellae, which are often almost spherical, tend more usually to be oval-shaped, presenting the appearance of being flattened on the apophysis. The membrane of the columella is light brown and smooth. In height the columellae were found to vary from 35 to 86 $\mu$, in width from 40 to 110 $\mu$. The spores, round, oval, or obtusely angular in shape and grayish-brown in colour, vary in length from 4.8 to 7.2 $\mu$, in width from 4.5 to 5.6 $\mu$. The walls are more or less clearly striated longitudinally. Chlamydospores (gemmae) were not observed.

## Identification of the Causal Organism

From the above observations and from others based on cultural studies which are described below, it was concluded that the causal organism is *Rhizopus arrhizus* Fischer[1]. In its morphology it corresponds with that species as described by Lendner (7) whose description is a summary of the original by Fischer. Identification was not rendered any less difficult by the fact that descriptions by later authorities do not always agree in regard to certain details either with the original or with one another. For example, in a key evolved by Lendner (7), the sporangiophores of *R. arrhizus* are designated as being *without* "nodosités". In 1914, Hanzawa (3) described the sporangiophores of *R. arrhizus* as often possessing vesicular swellings. It is not clear just what Lendner may have meant by the term "nodosité" but if he referred to vesicular swellings, then his description differs from that of Hanzawa in this detail. In 1939, Naumov (8) placed diagnostic emphasis on the absence of chlamydospores in the species, whereas Zycha (9) stated in 1935 that mycelial gemmae (presumably the same organism) are occasionally found. Naumov (8) also described the sporangiophores as being "pas nettement différenciés". No other authority consulted makes a similar statement. It is possible that on this point there is some discrepancy between Naumov's Russian idiom and the French translation. Hanzawa (3) records 10.8 $\mu$ as the maximum for spore length, whereas 7.0, 7.0, and 8.0 $\mu$ are the maxima for this dimension as recorded by Lendner (7), Zycha (9), and Naumov (8), respectively. Probably the various differences pointed out above are of minor diagnostic significance and represent only such variations as might well be expected to occur within a species.

As pointed out by Lendner (7) and by Hanzawa (3), *R. arrhizus* was first found by Fischer in 1892 on decaying capsules of Liliaceae and on immature currants. Since that time, according to Zycha (9), the fungus has been found

*A culture of the sugar beet isolate was sent to Mr. Victor M. Cutter, Jr., Department of Botany, Cornell University, Ithaca, N.Y., who, pending further detailed cultural studies, has tentatively confirmed the above diagnosis.*

widely distributed throughout Europe and North America on many different substrata including cultivated soil and thus may be regarded as one of the ubiquitous species of the genus.

## Effect of Temperature on Growth Rate and Pathogenicity of R. *arrhizus*, *R. nigricans*, and *R. oryzae*

It was shown above that *R. arrhizus* is a parasite capable of attacking artificially injured but otherwise healthy sugar beets growing under natural conditions in the field. Since the organism proved to be pathogenic under such relatively favourable circumstances, it seemed reasonable to expect that it might all the more readily attack mature, harvested beets which not only are injured in many ways during harvesting operations and in transit but which also, when "pitted" or piled, are subject to widely varying conditions before being finally processed. Moreover, it seemed hardly probable that only one *Rhizopus* species would possess pathogenic capability under such circumstances. Harter, Weimer, and Lauritzen (4) have shown that while *R. nigricans* is probably responsible for more decay of sweet potatoes in storage and in transit than any of eight other species, nevertheless, the latter will rot sweet potatoes. As these investigators further pointed out the species can be grouped into high, low, and intermediate temperature forms and the best results from inoculations were obtained when the sweet potatoes were incubated at the temperature best suited for the growth of the species with which the inoculations were made.

With the above considerations in mind it was decided to test the pathogenicity of *R. arrhizus* and of two additional species, namely, *R. nigricans* Ehrb. and *R. oryzae* Went et Pr. Geerligs, and to study in a very general way the influence of temperature on infection and decay of mature sugar beets as relating to these three species. Of the many species that might have been chosen, *R. nigricans*[1] was selected because, as pointed out above, this species has already been mentioned in the literature (Edson (2), Hodges (6) ) as a possible pathogen of the sugar beet. *R. oryzae* was selected because it was readily available, a representative of the species having been obtained by the authors from decaying leaves of newly-harvested flue tobacco coincidentally with the isolation of *R. arrhizus* from sugar beet. Before proceeding with the experiments on beets, cultural studies were carried out, as described below, to determine the effect of temperature on the growth rate of the three above-mentioned species of *Rhizopus*.

### A. Effect of Temperature on Growth Rate

The three species grew so satisfactorily on potato dextrose agar that, for the purposes of this experiment, it was not deemed necessary to try another medium. The following ranges of temperature were obtained by using Wisconsin temperature tanks and incubator ovens: 14 to 16°, 20 to 22°,

[1] *The authors are further indebted to Mr. Cutter (see footnote p. 240) for furnishing them with a culture of R. nigricans, the source of which though not definitely known is believed to have been a subculture of the original "Harvard strain" used by Blakeslee.*

24 to 26°, 29 to 31°, 34 to 36°, and 39 to 41° C. Three Petri dish cultures were grown for each species at each temperature. Thus, a single complete series comprised 54 plates. Final results were based on three successive series comprising a total of 162 plates. Small, uniform cubes of inoculum of each species were transferred to the centre of 90 mm. plates. At 24-hr. intervals, two measurements were made for each plate, one representing the greatest diameter of a colony, the other, the least. Thus was obtained a total of 18 readings for each species at each 24-hr. interval. Complete results based on the mean of these readings are presented in Table II, while the relative growth rates of the three species at the end of the first 24-hr. period are shown in Fig. 9.

TABLE II

EFFECT OF TEMPERATURE ON GROWTH RATE OF THREE SPECIES OF *Rhizopus*

| Temperature, °C. | Intervals, hr. | Diameter of colonies, mm. | | |
|---|---|---|---|---|
| | | *R. oryzae* | *R. arrhizus* | *R. nigricans* |
| 14 - 16 | 24<br>48 | 0<br>19 | 0<br>17 | 11<br>39 |
| 20 - 22 | 24<br>48 | 29<br>90 | 27<br>90 | 34<br>90 |
| 24 - 26 | 24<br>48 | 53<br>90+* | 50<br>90+ | 44<br>90 |
| 29 - 31 | 24<br>48<br>72 | 79<br>90+<br>90+ | 70<br>90+<br>90+ | 0<br>0<br>0 |
| 34 - 36 | 24 | 90+ | 90+ | 0 |
| 39 - 41 | 24<br>48<br>72<br>168 | 22<br>33<br>40<br>90+ | 22<br>35<br>37<br>90+ | 0<br>0<br>0<br>0 |

* *"90+" indicates that the colony had reached the wall of the plate before the end of the interval indicated.*

As reference to Table II will show, the growth of *R. nigricans* at 14° to 16° C. was well under way in 24 hr. while that of *R. arrhizus* and *R. oryzae* had not yet started. At the end of 48 hr. at this same temperature, all three species had made considerable growth, that of *R. nigricans* being about twice as great as that of either of the other two. In 24 hr. at 20° to 22° C., *R. nigricans* still surpassed in growth the other two species which, however, were growing much faster than at 14° to 16° C. In 48 hr. at 20° to 22° C., all three species had completely covered the plates. At 24° to 26° C., *R. nigricans* showed optimum growth but even so it was surpassed by both *R. arrhizus* and *R. oryzae.* At 29° to 31° C., even after 72 hr., *R. nigricans* showed no appreciable growth. The isolate was not killed, however, because plates left even a week at 29° to

31° C. soon showed growth after being transferred to room temperature in the laboratory. In marked contrast to the inability of *R. nigricans* to grow at 29° to 31° C., the other two species grew more rapidly than at any of the lower ranges. At 34° to 36° C., *R. arrhizus* and *R. oryzae* showed optimum growth, the colonies of both completely covering the plates in less than 24 hr. At 39° to 41° C., the growth of these two species, still paralleling one another very closely, was considerably retarded.

The above results show clearly that the isolate of *R. nigricans* used in the present studies is relatively a low-temperature organism as compared with *R. arrhizus* and *R. oryzae* and that the response to temperature on the part of the isolates of the two latter species is very similar (Fig. 9). These observations are in general agreement with those of most other investigators who have subjected the species in question to comparative physiological examination. For example, Harter and Weimer (5) in arranging species of *Rhizopus* according to what seemed to be the optimum temperature for infection of sweet potatoes and other hosts placed *R. nigricans* in the low-temperature group with optimum about 20° to 22° C., whereas *R. oryzae* and *R. arrhizus* were placed in the intermediate group with optimum about 30° C. It may be pointed out that the temperature at which *R. nigricans* stops growing has usually been reported as being somewhat higher than that recorded for the isolate involved in the present studies. Zycha (9), for example, stated that 10 *R. nigricans* strains studied by him stopped growing at 37° C., and he refers to other writers who mention 35° C. in this connection. Ames (1) reported that a strain of *R. nigricans* isolated from sweet potato grew best at 36° C., and only stopped growing at 42° C. Zycha (9) comments that Ames' observation "scheint nicht der typisch *Rh. nigricans* zugrunde gelegen zu haben." The isolate of *R. nigricans* used in the present studies is known to have been perpetuated in culture for several years and this may have contributed to its failure to grow at 29° to 31° C.

### B. Effect of Temperature on Pathogenicity

Sugar beets that had been harvested from laboratory plots in October, 1942, and stored subsequently in a dry, cool root cellar, were used in testing the pathogenicity of the three *Rhizopus* isolates. These beets, when harvested, instead of being topped by slicing off a portion of the crown as in commercial practice, were left uninjured, the foliage having been clipped off close to the crown without injury to the latter. In November, beets approximately uniform in size and apparently free from disease were selected from among those in storage. After thorough washing and re-examination for injury or infection of any kind, the beets were planted in compost soil in Wisconsin temperature tanks (one beet per container). After two days, when beets and soil had become stabilized at the temperatures at which the different tanks were being operated, namely, 14 to 16°, 20 to 22°, 29 to 31°, and 39° to 41° C., inoculation was completed. In each tank two roots were inoculated with each of the three isolates and two roots served as checks. After removing

temporarily a portion of the soil, each root was artificially injured at two points spaced 3 to 4 in. apart, by removing with a sharp scalpel a wedge-shaped strip of tissue about $1 \times \frac{1}{4} \times \frac{1}{4}$ in. Inoculum was applied to each of the injuries as well as to a small circular area of uninjured root surface,

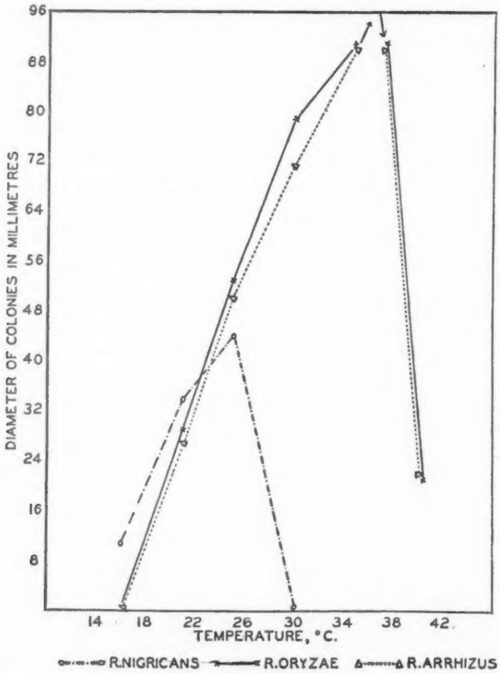



FIG. 9. *Effect of temperature on the growth rate of representatives of three species of Rhizopus on potato dextrose agar by the end of a test period of 24 hours.*

the inoculated area being covered with a pad of moistened cotton before the soil was replaced about the root. The checks were treated in an identical manner except that sterile agar replaced the fungous inoculum. The soil was kept moist but no attempt was made to control this variable since it was considered that infection would be governed more by moisture within the root than that in the soil around it. At 4-, 7-, 11-, or 21-day intervals sufficient examinations were made of roots at the different temperatures to permit comparison of degree of injury and progress of infection. A root removed for examination was cut longitudinally in a median plane through the point of inoculation and the outline of a lesion thus exposed was traced on squared paper. In this way areas of lesions could be computed, compared, and the progress of infection followed. The experiment was repeated three times in as exact detail as possible. Thus, for each of the three species under test,

the results of 12 wound and 6 contact inoculations were available for comparison with those of other series. Areas of lesions for a given series, obtained as described above, were averaged and the final results of the completed experiment are shown graphically in Fig. 10.

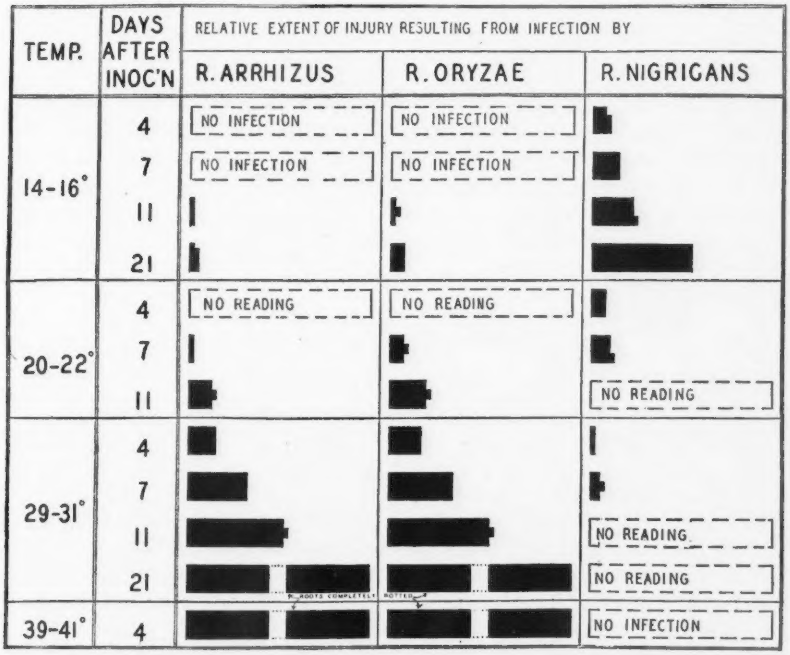



FIG. 10. *Effect of temperature on the pathogenicity of representatives of three species of Rhizopus on harvested sugar beets.*

In describing the results it may be pointed out in the first place that the representatives of the three different species all proved to be strictly wound parasites. In not a single instance where inoculum was applied to an uninjured root surface did infection follow, and all checks remained healthy. In regard to wound inoculations, however, strikingly different results were obtained, for under such circumstances, and conditioned by temperature, all three species possessed marked pathogenic capability. Referring to Fig. 10, it will be noted that the effect of temperature on infection by *R. nigricans* on the one hand and on *R. arrhizus* and *R. oryzae* on the other, was quite different. In only four days at 14 to 16° C., *R. nigricans* was able to cause appreciable damage and in 21 days roots were seriously affected. In marked contrast, *R. arrhizus* and *R. oryzae* did relatively little damage to root tissues at this temperature even after 21 days. At 20° to 22° C., the picture changed.

The severity of damage caused by *R. nigricans* decreased whereas that due to the other two species increased. At 29° to 31° C., *R. nigricans* showed little more than trace infection whereas the capabilities of *R. arrhizus* and *R. oryzae* in this regard had increased to the point of causing serious damage in only 11 days and complete destruction of the roots in 21. At 39° to 41° C., infection by the two last-mentioned species spread so rapidly that roots were completely rotted in only four days.

*R. nigricans* differed from the other two species not only in its reaction to temperature but also as regards certain characteristics of the lesions it produced. The latter were, in general, more deeply brown in colour and their margins, as a result, more clearly delimited from adjacent healthy tissue than those caused by the other two species. While *R. arrhizus* and *R. oryzae* were both high-temperature organisms and paralleled one another very closely in their infection capabilities, it was observed, nevertheless, that *R. arrhizus* "lagged" appreciably behind *R. oryzae* except at the higher temperatures. This same tendency on the part of *R. arrhizus* was noted in studying its growth on potato dextrose agar (Fig. 9). As far as *R. arrhizus* is concerned, the results of these greenhouse experiments carried out under at least partial control of environmental conditions, confirm those completed earlier under natural field conditions, namely, that the organism, though a wound parasite, can display virulence to a high degree.

## Discussion

As a result of the above investigations, sugar beets must now be definitely included in the long list of fruits and vegetables that are subject to decay by species of the genus *Rhizopus*. Why this particular type of disease should have made its appearance in an isolated experimental plot miles distant from the nearest commercial planting and on beets in soil that had never before been planted to this crop, is difficult to understand. True, the soil, a light sandy loam, is of a type known to be unsuitable for sugar beets but this alone would not seem to be a predisposing factor of sufficient importance to account for the occurrence of the disease. That the causal agent was already present in the soil is quite possible, since as pointed out in a preceding section of the present paper, *R. arrhizus* is known to have a wide distribution in cultivated soils. That the beets were injured by some agent at present unknown must also be assumed since all the evidence points to the fact that *R. arrhizus*, as well as *R. oryzae* and *R. nigricans*, is a wound parasite that requires an infection-court of considerable proportions for initial stages of infection. Of the two variables, temperature and moisture of the soil, which, in general, are of outstanding significance in the incidence and severity of root rots of various hosts, the former is undoubtedly the more important in the present case. *R. arrhizus*, which in culture grows best at about 34° to 36° C., would thrive at the relatively high temperatures that prevail in the soils in this part of Ontario during the summer months, and, once having gained entry into the root of a sugar beet, would find ample moisture for further rapid development.

Whether or not the disease has ever before occurred in the field in Ontario is a matter of speculation. It is not improbable that it has been present but has not been distinguished from root rots caused by other agents. There is reason to believe, however, that the disease may have occurred in harvested beets. Enquiry by the writers has disclosed that, over a period of years in Ontario, considerable losses have been incurred in beets assembled in piles at concentration points, as the result of a rot the symptoms of which are strongly suggestive of those resulting from infection by *Rhizopus*. Circumstances attendant upon the outbreak of this particular type of decay have included storage of immature beets which subsequently "sweated" and heated in the piles. It can readily be understood how rapidly *R. arrhizus* or *R. oryzae* could destroy beets under such circumstances or how, further, *R. nigricans* with its different temperature requirements might become operative under an entirely different set of conditions.

In certain respects the findings of the present study have closely paralleled those of investigators who, some two decades ago, studied the decay of sweet potatoes caused by different species of *Rhizopus*. For example, just as Harter, Weimer, and Lauritzen (4) found that nine species of *Rhizopus* capable of attacking this host could be grouped into high, low, and intermediate temperature forms, so too, the writers found that the optimum temperature for infection of sugar beets by different species of the genus differed by at least 10° C., *R. arrhizus* and *R. oryzae* being representatives of high temperature forms whereas *R. nigricans* is a low temperature form. Similarly, as reported by the above-mentioned investigators in their work on sweet potatoes, the present authors found that best results from inoculations were obtained when sugar beets were incubated closest to the temperature best suited for the growth of the species with which the inoculations were made. Harter and Weimer (5) found that under laboratory conditions certain species of *Rhizopus* were vigorous parasites and yet in nature none of these species were encountered as frequently as *R. nigricans* which seemed to be the immediate cause of most of the decay of the particular host in question. In the present investigations the writers found that under laboratory conditions *R. oryzae* was more virulent in its attack on sugar beets than was *R. arrhizus*, yet the former species was never isolated from affected beets.

If these studies had been extended to include additional species of *Rhizopus*, it seems almost certain that some at least of the latter would have been found capable of parasitizing the sugar beet. Probably, also, some of them would have been found to have optimum temperature for infection midway between that of *R. arrhizus* and *R. oryzae* on the one hand and *R. nigricans* on the other. Such findings, however, would not add materially to the important practical implications suggested by the investigation in its present dimensions, namely, that certain species of *Rhizopus* constitute a potential threat to sugar beets, especially those that have been injured in harvesting operations or in transit and subsequently stored in a condition or under conditions conducive to infection by these organisms.

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# THE MICROFLORA OF THE RHIZOSPHERE OF TOMATO PLANTS IN RELATION TO SOIL STERILIZATION[1]

By H. Katznelson[2] and L. T. Richardson[3]


## Abstract

Sterilization brings about significant changes in the physical and chemical, as well as biological properties of soil which thus becomes a different and often more favourable medium for microbial activity. In an investigation of a root rot of greenhouse tomatoes marked differences in numbers of fungi, bacteria, and actinomycetes were noted in both soils and rhizospheres as a result of sterilization with steam, chloropicrin, and formaldehyde. Roots invariably supported much higher numbers of the three groups of organisms studied, thus displaying the common "rhizosphere effect". Numbers of bacteria were considerably greater on infected than on healthy roots.

Qualitative differences in fungi and bacteria were also noted in both soils and rhizospheres. Of particular interest was the tendency for bacteria with simple food requirements and those stimulated by amino acids to predominate in the rhizosphere, and for those with more complex nutritional needs to predominate in soils apart from the roots.

It is suggested that such nutritional investigations of rhizospheres may be useful in studies on the physiological activity of plant roots.


In the course of an investigation at the Dominion Laboratory of Plant Pathology, St. Catharines, Ont. on the effect of soil sterilization on the incidence of a root rot of greenhouse tomatoes caused by an unidentified biological agent, a qualitative and quantitative study of the soil and root microflora was made to note any relationship between the root rot factor and the microbial populations of the soils and roots. The data obtained are summarized in this paper.

## Experimental

A soil known to contain the root rot factor was divided into four lots and treated as follows:

*US*—Unsterilized (control)
*FS*—Formaldehyde-sterilized
*CS*—Chloropicrin-sterilized
*SS*—Steam-sterilized

Tomato seedlings were transplanted into each soil one month after the treatments were applied and samples for microbiological study were taken when the plants were mature. The results obtained at that time were considered sufficiently interesting to warrant repetition of the entire experiment. Since the data from both experiments are essentially similar, only those from the second trial are presented.

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Samples of soil were taken one month after sterilization and of soils and roots two and six months later. Six soil samples from each treatment were composited and mixed thoroughly. The plants were carefully removed and the loose soil shaken from their roots. Soils and roots were plated on soil extract agar for bacteria and actinomycetes (2, 4) and on acidified potato dextrose agar for fungi; bacterial counts were made after 12 days, at which time all the colonies on sections of representative plates were picked into soil extract semisolid agar for qualitative studies according to the method of West and Lochhead (7). Other root samples, with lesions where possible, were thoroughly washed in running water, rinsed in sterile water and cut into $\frac{1}{4}$-in. pieces which were placed on acidified and non-acidified potato dextrose agar for a study of the predominant fungi intimately associated with the lesions, or with the roots themselves where lesions were absent (5). The fungi were identified, as to genera, directly from the plates or from pure cultures grown from isolated hyphal tips.

When examined after two months the plants showed a distinct difference in appearance as a result of treatment. Plants from unsterilized soil were stunted, thin, and weak; steam and chloropicrin produced the healthiest and formaldehyde, intermediate specimens. Abundant extensive dark brown lesions were found on roots of plants in unsterilized soil. Steam and chloropicrin sterilization resulted in clean white roots, but formaldehyde was not quite so efficient since a number of the roots were infected. After six months the above symptoms were much more pronounced. Yields reflected the same general picture.

## Quantitative Results of Soil Sterilization

In Table I are presented quantitative data on the influence of soil sterilization on the microbial populations of the soils and rhizospheres. Chloropicrin and formaldehyde applications resulted in large increases in numbers of fungi, but steam appeared to exert a deleterious influence evident even after three months. Fungi were very abundant in all rhizospheres, though slightly less so on roots in chloropicrin soil than on those in the other soils. No correlation between degree of root infection and numbers of fungi was detected.

Bacterial counts were higher in soils that had been sterilized; this is the usual condition in soils after partial sterilization. Numbers were much greater in rhizospheres; they were particularly high on infected, decomposing roots (in unsterilized soil and to some extent in formaldehyde treated soil), especially after seven months. These findings are similar to those of Hildebrand and West (1) for strawberry root rot.

Numbers of actinomycetes in soil apart from the root were lowered appreciably by steam. These organisms were very abundant in the rhizospheres and particularly so on roots in chloropicrin treated soil, and on roots in steamed soil in the last sampling. On the other hand formaldehyde reduced the number of these forms in the rhizosphere.

TABLE I

INFLUENCE OF SOIL STERILIZATION ON MICROBIAL POPULATIONS OF SOILS AND RHIZOSPHERES

| Soil treatment | Sampling period, months | Fungi (thousands) | | Bacteria (millions) | | Actinomycetes (millions) | |
|---|---|---|---|---|---|---|---|
| | | Soil apart from root* | Rhizosphere** | Soil apart from root | Rhizosphere | Soil apart from root | Rhizosphere |
| Unsterilized | 1 | 12 | – | 48 | – | – | – |
| | 3 | 10 | 360 | 44 | 2320 | 5 | 40 |
| | 7 | 14 | 427 | 51 | 2840 | 3 | 18 |
| Formaldehyde | 1 | 51 | – | 223 | – | – | – |
| | 3 | 26 | 310 | 171 | 1870 | 4 | 17 |
| | 7 | 50 | 376 | 78 | 2080 | 2 | 8 |
| Chloropicrin | 1 | 49 | – | 104 | – | – | – |
| | 3 | 10 | 230 | 136 | 1830 | 4 | 114 |
| | 7 | 12 | 130 | 113 | 1200 | 4 | 52 |
| Steam | 1 | 0.1 | – | 243 | – | – | – |
| | 3 | 1.0 | 350 | 347 | 1620 | 0.6 | 40 |
| | 7 | 16.0 | 588 | 90 | 930 | 1.2 | 85 |

* *Soil counts—per gram oven-dry soil.*
** *Rhizosphere counts—per gram dry root.*

## Qualitative Results of Soil Sterilization

The information summarized in Table II was selected from the last sampling and is representative of the results obtained. It is evident that a large proportion of the bacteria isolated falls into the nutritional group of organisms requiring soil extract semisolid or yeast extract medium, a fact observed by Lochhead and Chase (3) in soils of different fertility. These organisms are in all cases more numerous in soils than in the corresponding rhizospheres. Similar results were reported by West and Lochhead (6) in qualitative studies of the rhizospheres of flax and tobacco. On the other hand bacteria producing maximal growth (Group 3), or either maximal and submaximal growth (Groups 1, 2, 3, 4, 6, 8 = $\%B$) in a mineral–glucose medium (7) are more numerous in the rhizospheres. This also has been observed with flax and to some extent with tobacco (6). The bacterial balance index is calculated by assigning a negative value to the percentage occurrence of Group 3 bacteria, a positive value to bacteria of Groups 5, 7, and 9, which grow only in a medium containing amino acids or growth factors (1), and adding the resulting figures. West and Hildebrand (5) found a low index to be associated with incidence of a factor causing brown rot of strawberry roots. In the present study, the index of the rhizosphere of roots in unsterilized soil was lower, though not strikingly so, than that of roots in sterilized soils. The index was lower in rhizospheres than in soils except where formaldehyde was used. The results of West and Lochhead (7) for flax and tobacco indicate the existence of larger numbers of bacteria, stimulated by amino acids, on root surfaces than in soil

TABLE II

EFFECT OF SOIL STERILIZATION ON THE PREDOMINANT BACTERIAL NUTRITIONAL GROUPS IN SOILS AND RHIZOSPHERES

| Nutritional groups | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *US* | | *FS* | | *CS* | | *SS* | |
| | *S** | *R*** | *S** | *R*** | *S** | *R*** | *S** | *R*** |
| Sum of % organisms growing in soil extract semisolid or yeast extract medium only | 58 | 41 | 67 | 55 | 75 | 23 | 57 | 47 |
| % Gram-negative bacteria growing well in mineral-glucose medium (Group 3) | 3 | 23 | 5 | 12 | 0 | 18 | 0 | 13 |
| Sum of % organisms producing maximal or submaximal growth in mineral-glucose medium (Groups 1, 2, 3, 4, 6, 8 = %*B*) | 15 | 34 | 17 | 22 | 7 | 47 | 11 | 23 |
| Bacterial balance index | +25 | +3 | +12 | +12 | +18 | +10 | +30 | +18 |
| Sum of % organisms stimulated by amino acids (Groups 4, 5, 6, 7) | 10 | 18 | 7 | 14 | 15 | 26 | 9 | 17 |

* *S = soil.*
** *R = rhizosphere.*

apart from the root. Similar results were obtained in the present study as is shown in the last line of Table II. It is interesting to note the stability of these nutritional groups in both soils and rhizospheres since no striking relationships between soil treatment and incidence of these groups was evident. This is in accord with the observation by Lochhead and Chase (3), that "The incidence of the different (nutritional) groups does not appear to reflect markedly the pronounced difference in crop producing capacity" of the soils studied.

The dynamic nature of the microbiological equilibrium in soils and rhizospheres was also brought out by the data, an example of which is presented in Table III. Group 3 bacteria and those considered as %*B* increased in the rhizosphere with time, resulting, in part at least, in a decrease of the bacterial balance index. The reverse trend appears to take place in the soil.

Table IV contains data on the types of fungi predominating in the soils and rhizospheres. These studies were made from plates used in the quantitative determinations; plates with a 1 : 1000 dilution were used for soil apart from roots, and 1 : 10,000 dilution for rhizospheres. *Aspergillus* and *Fusarium* species and members of the Phycomycetes (*Mucor*, *Rhizopus*) were not abundantly represented. *Trichoderma* was present in large numbers in both soils and rhizospheres, particularly on roots in unsterilized soil after seven

TABLE III

INFLUENCE OF TIME ON THE INCIDENCE OF CERTAIN NUTRITIONAL BACTERIAL GROUPS IN UNSTERILIZED SOIL

| Sampling period, months | Nutritional groups | | | | | |
|---|---|---|---|---|---|---|
| | Group 3 | | % *B* | | Bacterial balance index | |
| | *S** | *R*** | *S** | *R*** | *S** | *R*** |
| 1 | 3 | – | 23 | – | + 8 | – |
| 3 | 8 | 10 | 19 | 18 | +11 | +23 |
| 7 | 3 | 23 | 15 | 34 | +25 | + 3 |

* *S* = *soil.*
** *R* = *rhizosphere.*

TABLE IV

FUNGI ISOLATED FROM DILUTION PLATES OF SOILS AND RHIZOSPHERES (NUMBERS PER 1/1000 GM.)

| Genus | Sampling period, months | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 3 | | | | | | | | 7 | | | | | | | |
| | Treatment | | | | | | | | | | | | | | | | | | |
| | *US* | *FS* | *CS* | *US* | | *FS* | | *CS* | | *SS* | | *US* | | *FS* | | *CS* | | *SS* | |
| | *S** | *S* | *S* | *S* | *R*** | *S* | *R* | *S* | *R* | *S* | *R* | *S* | *R* | *S* | *R* | *S* | *R* | *S* | *R* |
| ***Aspergillus*** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Fusarium*** | 1 | 2 | – | – | 20 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Mucor*** | 2 | – | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Plectonaemella*** | – | 1 | – | – | – | 1 | – | – | – | – | – | – | – | 14 | 320 | – | – | – | – |
| ***Penicillium*** | | | | | | | | | | | | | | | | | | | |
| Green | 4 | 1 | – | 3 | 40 | 7 | 30 | – | 20 | 2 | 10 | – | 20 | 7 | 40 | 5 | – | – | – |
| Blue-green | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 10 | 560 |
| Gray-green | – | – | – | – | – | – | – | 5 | – | – | – | 5 | 20 | – | – | – | 310 | – | – |
| Yellow-green | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 10 |
| Purple | 4 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Rhizopus*** | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Sporotrichum*** | – | 3 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| ***Trichoderma*** | 2 | 6 | 9 | 2 | 60 | 4 | 80 | 5 | 50 | – | 70 | 6 | 370 | 7 | 80 | 3 | 70 | 3 | 40 |
| Unidentified | – | 2 | – | 1 | 20 | – | 30 | – | 30 | – | 10 | – | 20 | – | 20 | 2 | – | – | 10 |

* *S* = *soil.*
** *R* = *rhizosphere.*

months. *Plectonaemella* (tentatively identified) increased sharply in the last sampling in formaldehyde treated soil but even more so in the rhizosphere. Green forms of *Penicillium* were fairly numerous and varied somewhat in frequency and form with the treatment. A yellow-green form appeared in the rhizosphere of roots in steamed soil at seven months; a gray-green species was present in large numbers in the rhizosphere of roots in chloropicrin treated soil in the last plating and a blue-green member of the genus appeared, at the same time, in great abundance in both soils and rhizospheres of the steam-sterilized series.

Certain fungi with pathogenic capabilities grow slowly on agar media and are often obscured, or inhibited, in dilution plates by rapidly growing forms such as *Trichoderma*, *Penicillium*, and *Rhizopus*; they may also be diluted out in the course of plating; this is especially true of sterile imperfect fungi. Such forms can often be isolated directly from root sections as the results in Table V indicate. *Cylindrocarpon*, a species frequently associated with root rots (5), appeared on roots in unsterilized soil after three months and on all roots in the last plating. A certain sterile imperfect fungus[1] was abundant only in badly infected roots (in unsterilized soil). Various species of *Fusarium* and *Penicillium* were present and *Trichoderma* was very abundant. *Aspergillus*, *Mucor*, *Rhizoctonia*, *Pythium*, and unidentified pycnidial forms appeared in the last sampling period.

TABLE V

NUMBER AND TYPE OF FUNGI ISOLATED FROM ROOT SECTIONS OF PLANTS GROWING IN INFESTED AND PARTIALLY STERILIZED SOIL

| Genus | Sampling period, months | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | | | | 7 | | | |
| | *US* | *FS* | *CS* | *SS* | *US* | *FS* | *CS* | *SS* |
| *Aspergillus* | – | – | – | – | 2 | 1 | – | 4 |
| *Cylindrocarpon* | 1 | – | – | – | 7 | 5 | 2 | 2 |
| *Fusarium* | 5 | 10 | – | 1 | 4 | 8 | 4 | 2 |
| *Hormodendrum* | – | – | – | 1 | – | – | – | – |
| *Mucor* | – | – | – | – | 2 | 1 | 1 | 1 |
| *Penicillium* | 15 | 10 | 3 | 6 | 9 | 11 | 6 | 15 |
| *Pythium* | – | – | – | – | 4 | 5 | 2 | 10 |
| *Rhizoctonia* | – | – | – | – | – | 2 | – | – |
| *Rhizopus* | 2 | 1 | 1 | – | 2 | – | – | 1 |
| Sterile imperfect | 7 | 1 | – | – | 10 | – | – | – |
| *Trichoderma* | 37 | 25 | 30 | 37 | 16 | 12 | 10 | 22 |
| *Verticillium* | – | – | 1 | – | – | – | – | – |
| Unidentified pycnidial forms | – | – | – | – | 6 | 5 | 2 | 5 |

## Discussion

Soil sterilization is an effective, commonly employed means of controlling soil-borne plant parasites in greenhouses and was successfully used in these experiments. However, the concomitant changes of the microbial populations of the treated soils and of the rhizospheres of the plants growing in these soils have received little attention, yet it is evident from the data presented that such changes do occur and are, in some instances, quite appreciable, especially as the soils recover from the treatment and as the plants mature (Tables I, IV, V).

Of particular interest is the "rhizosphere effect" observed regardless of the treatment. Numbers of bacteria, fungi, and actinomycetes are always much

[1] *This fungus has been isolated frequently from these lesions by J. K. Richardson, who has obtained evidence of its pathogenicity to tomato roots from soil inoculations.*

higher on root surfaces than in soil apart from the plant. Furthermore the roots support larger numbers of bacteria stimulated by amino acids and forms with very simple nutritional requirements than do the corresponding soils. On the other hand the soils contain a larger proportion of bacteria requiring certain unidentified substances in yeast extract and soil extract semisolid agar media. The resulting microbiological balance undoubtedly reflects, to some extent at least, the physiological activity of the root.

It is apparent that only by thorough qualitative and quantitative studies, such as were attempted in the above experiments, can an understanding of the complex, delicately balanced forces operating in the zone of interaction of soils and roots be achieved. By such means indirect evidence of the physiological behaviour of roots themselves may also be obtained.

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## STUDIES OF WATERFOWL IN BRITISH COLUMBIA

### MALLARD[1]

BY J. A. MUNRO[2]

### Abstract

*Anas platyrhynchos* is widely distributed along the Pacific coast. The main winter range extends from coastal Alaska to northern California with the greatest concentration in the lower Fraser Valley of British Columbia and adjacent counties in Washington State. To this coastal plain come summer populations from interior British Columbia, Alberta, Yukon Territory, and Alaska. Here also is a relatively small resident population. A winter population in the interior is increasing in numbers. Migration routes follow the coast and the main river systems, the latter leading to a wide highway of dispersal along the interior plateaux. Band recoveries identify these migration highways and the seasonal movements; they show that mallards follow the same general routes, return in successive years to the same wintering grounds and that population units remain together. On the southern coast nesting commences early and downy young have been seen in March and April. In the interior the majority nest in May and many different types of nesting habitats are occupied. Males leave the females after incubation has started and by early June many, still in full breeding plumage, have gathered in flocks. Subsequently as males start to eclipse they become less gregarious. When the flight feathers are renewed the males again assemble in flocks that later are joined by females and flying young. On the coast one winter population feeds chiefly on seeds and vegetation, secured on flooded fields; another feeds exclusively on salmon eggs and salmon flesh; a third, occupying the littoral, on algae and small marine animals. In the interior the seeds of aquatic plants, more particularly *Scirpus acutus* and *Potamogeton pectinatus* are important foods, so are aquatic insects chiefly Odonata nymphs and corixids. One population in autumn lives almost entirely on grain secured from the fields. The mallard is the duck species of greatest economic importance in British Columbia and the source of a considerable item of revenue to the province. This value is believed to outweigh an economic loss of undetermined proportion brought about by the mallards' consumption of salmon eggs and damage to agricultural crops.

### Introduction

The mallard, *Anas platyrhynchos* Linnaeus, is more widely distributed, geographically, in British Columbia than is any other duck species. It is quickly adaptable in respect of nest and food requirements and both its breeding and winter ranges include a variety of diverse habitats. It is abundant and in certain localities during late autumn may outnumber the total of all other ducks present. It is the species bearing the heaviest hunting

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*Contribution from the National Parks Bureau, Department of Mines and Resources, Ottawa, Canada.*
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pressure and yet is the only one that appears to have maintained its numbers or actually increased during the past 20 years.

The present paper records the distribution and migration of the species in western North America and the behaviour, general life history, numerical status, and food habits as studied in British Columbia. The section on distribution and migration is based on an analysis of data provided by the recovery of banded mallards, and supplemented by field observations conducted since 1911. The section on food habits is the sum of field observations during this period supplemented by the study of food in the stomachs of 218 specimens.

## Distribution and Seasonal Movements

### Coast Region

During the years 1928 to 1940, inclusive, a total of 17,395 mallards was banded at five stations in British Columbia. The ducks were captured in poultry netting traps baited with wheat and constructed so that a funnel-shaped entrance was in shallow water and the greater part of the trap on land. A total of 3387 bands has been recovered and reported as at January 31, 1943. Of this total 2516 were taken in the first year after banding and the remainder as follows: 2nd year, 510; 3rd year, 189; 4th year, 186; 5th year, 35; 6th year, 24; 7th year, 14; 8th year, 2; 9th year, 1; 10th year, 1.

Five banding stations were operated as follows: (1) McGillivray Creek Game Reserve, near Sardis, conducted as a joint project of the National Parks Bureau and the Provincial Game Commission; (2) Pitt Meadows near Port Coquitlam, operated by the Provincial Game Commission on the property of Mr. A. L. Hagar; (3) Westham Island, at the mouth of the Fraser River, operated by Mr. George C. Reifel; (4) Vaseaux Lake, Okanagan Valley; (5) Buffalo Lake, Cariboo District, operated by the National Parks Bureau.

The distance from Station 1 to Station 3 is approximately 55 miles true west, the distance from Station 3 to Station 2 approximately 22 miles true northeast, and the distance from Station 1 to Station 2 approximately 30 miles true northwest. Being situated close together on the wintering ground along the Coastal Plain, Stations 1, 2, and 3 are regarded as a unit and the data have been combined for statistical purposes. Stations 4 and 5, situated on migration flyways in the interior and 180 airline miles apart, are treated separately. The totals of mallards banded and the totals of returns for each station are shown in Table III. A summary of returns by provinces, states, and territories is given in Table IV. See also Fig. 1.

Recoveries are classified in the following categories, viz., Coastal Plain, current year, 1687 or 49.9%, later years 1014 or 29.5%, Table V; southeast and west Coastal Plain, current, 48 or 1.5%, later years, 184 or 5.7%, Table VI; winter recoveries north of Coastal Plain, 9 or 0.2%; transient spring and summer, first year, 43 or 1.2%, later years, 33 or 1%; transient autumn, north of Coastal Plain, 225 or 6.8%, Table VIII; Vaseaux Lake, 68 or 2%, Table X; Buffalo Lake, 76 or 2.2%, Table XI.


FIG. 1. *Dispersal of mallards banded in British Columbia. Each dot represents one or more recoveries. One recovery from Missouri and one from Illinois are not included; each star represents a banding station.*

### *Winter*

The wintering ground of mallards on the Pacific Coast is included within a wide latitudinal range from Alaska to California (Table VI). Current recoveries, that is, bands recovered during the autumn and winter banding season, and recoveries in later years bring out the fact that the greatest concentrations take place in a rather limited area referred to here as the Coastal Plain. The Coastal Plain is defined as the delta and valley of the Fraser River and its tributaries east to the vicinity of Rosedale, the southeast coast of Vancouver Island and the Gulf Islands, and that part of the Puget Trough in the Washington counties of Whatcom, Skagit, Snohomish, King, San Juan, and Island. This unit of territory probably constitutes the most densely populated area in western North America. A total of 2701 band recoveries come from this region as compared with a total of 241 from all other points on the coast.

TABLE I

FOOD OF MALLARD, TOTAL PERCENTAGE VOLUME

| Locality and number of specimens | | Salmon eggs | Corixids | Odonata | Miscellaneous insects | Molluscs | Miscellaneous animals | Round-stem bulrush seeds | Miscellaneous seeds | Grain | Miscellaneous vegetation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Fraser Valley | 90 | | | | | | | | 62.61 | 2.94 | 34.65 |
| Pitt Meadows | 6 | | | | | | | | 100.00 | | |
| Boundary Bay | 3 | | | | | 35.00 | 45.00 | | 20.00 | | |
| Southern Vancouver Island | 5 | | | | 33.60 | 4.00 | | | 20.40 | 18.00 | 24.00 |
| Departure Bay | 2 | | | | | 7.50 | 40.00 | | 5.00 | | 47.50 |
| Seal Island | 1 | | | | | 50.00 | | | | | 50.00 |
| Henderson Lake | 6 | 65.00 | | | | | 35.00 | | | | |
| Quinsome Lake | 5 | 74.00 | | | | | 10.00 | | | | 16.00 |
| Swan Lake, Okanagan | 85 | | 18.45 | 22.94 | 0.56 | 0.83 | 0.07 | 28.54 | 9.24 | 6.78 | 12.59 |
| Okanagan Region | 5 | | 1.00 | 2.25 | | | 13.25 | | 57.00 | | 26.50 |
| Cariboo Region | 9 | | 0.11 | 1.11 | 2.44 | 13.00 | 11.00 | 13.89 | 25.42 | | 33.00 |
| Babine Lake | 1 | 95.00 | | | 5.00 | | | | | | |

The main flights reach the Coastal Plain usually in November, the time varying considerably from year to year and apparently being largely controlled by temperature; if freezing conditions occur in the north early in the autumn there is an early migration while high temperatures in the north retard the migration (Figs. 2, 3). The following show the dates in each banding year when the largest number were captured at Station 1 and probably approximate the time of the migration peak for these years:

| Date | No. captured | Date | No. captured |
|---|---|---|---|
| 1928, November 9 | 190 | 1935, November 12 | 127 |
| 1930, November 4 | 84 | 1936, October 25 | 42 |
| 1931, November 14 | 87 | 1937, November 2 | 209 |
| 1932, November 22 | 130 | 1938, December 2 | 113 |
| 1933, December 10 | 180 | 1939, November 16 | 184 |
| 1934, November 6 | 245 | | |

A large number of the 1687 current recoveries on the Coastal Plain were made shortly after the ducks were banded, some actually on the same day and within a few miles of the banding station, others several months later either at places close to the station or at relatively distant points within the Coastal Plain. Thus 639 of the 1614 recoveries from mallards banded at

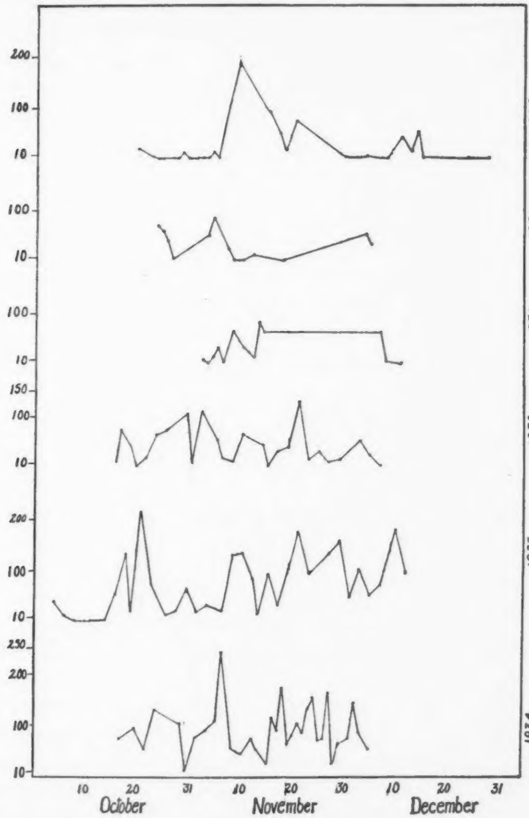


FIG. 2. *Daily catch of mallards at Station 1, October to December inclusive; 1928 and 1929 to 1934.*

Station 1 came from places one to six miles distant, 17 came from Vancouver Island, 558 from points between these extremes of east and west, and 400 from Washington State. Two of the latter were short-time recoveries indicating the distance travelled in one day. One banded at Station 1 on December 22, 1933, was shot at Mt. Vernon, Wash., approximately 45 miles south, on the same day, and one banded at Station 1, November 17, 1928, was shot at Blaine, Wash., 25 miles southwest on the following day.

Results at Station 3 were similar. Fifty were recovered at points one-half to five miles from the station, one at Sardis, 13 from intermediate points, and nine from Washington State.

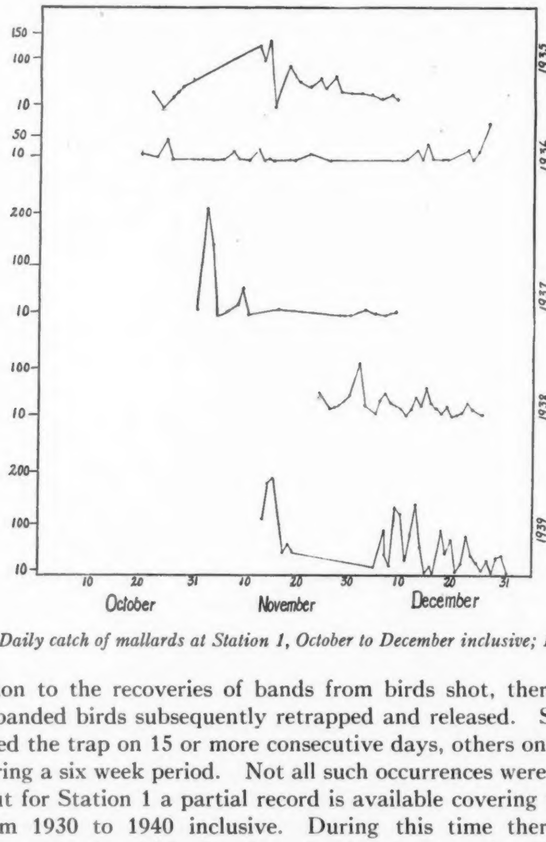


FIG. 3. *Daily catch of mallards at Station 1, October to December inclusive; 1935 to 1940.*

In addition to the recoveries of bands from birds shot, there are many records of banded birds subsequently retrapped and released. Some individuals entered the trap on 15 or more consecutive days, others on as many as 20 days during a six week period. Not all such occurrences were recorded at the time but for Station 1 a partial record is available covering the banding periods from 1930 to 1940 inclusive. During this time there were 141 recorded recoveries in which the time elapsing between banding and last subsequent recovery approximated one week; 123, two weeks; 65, one month; 26, two months; 13, three months; and 3, four months. These data, which have not been tabulated, are of similar value to those referred to as current recoveries.

The significance of current trap recoveries alone could be questioned because the attraction of food in the trap may have been the factor controlling the return of the birds. But as these recoveries parallel local recoveries of birds shot they are considered acceptable. It is necessary also to mention another factor of considerable importance that influenced the movements of mallards in the region adjacent to Station 1. This station was located on a Game

Reserve where shooting was prohibited. The protection thus afforded and the presence of grain were responsible for a daily concentration of mallards in this area.

In spite of these two potent attractions, however, there was considerable variation in the movements of individual mallards. Some returned daily, others after an absence of a week, a month, or longer. Thus there seems no reason to modify the conclusions summarized in the following paragraph.

In mild, wet winters on the Coastal Plain fields are flooded, thus ensuring a plentiful food supply for mallards. It is well known through observation that flocks are to be found daily on certain feeding grounds in various localities. There was no means of knowing, however, whether these populations consisted of the same individuals present from day to day, or week to week, or whether one population moved out and was replaced by another. Data provided by banded birds shot and by current trap recoveries show that some individuals are sedentary while others move from one district to another and back again. There is no general shift of the population except that brought about by a sudden drop in temperature which freezes surface water and drastically reduces the food supply.

The most definite fact that emerges from the study of current recoveries is that mallards concentrate on the Coastal Plain and that this area probably supports the largest winter population on the Pacific Coast. This conclusion is strengthened by the high percentage of later recoveries from the region. These, 1014 in number, show that mallards return to the same wintering grounds on the Coastal Plain and trap recoveries show that some return to the precise locality. Thus a mallard banded at Station 1 on November 19, 1933, was recaptured there on November 26, 1934; another banded at Station 1, December 19, 1938, was recaptured there December 22, 1939. There are 78 records of banded mallards that were recaptured a year or more later at the same station (Table XIII).

These data analysed below further emphasize the point. Station 1. Eight hundred and sixty-two recoveries of which 187 or 21.7% came from localities within 15 miles of the station; first year, 86; second year, 70; third year, 15; fourth year, 10; 2 each in fifth, sixth, and eighth years. Station 2. One hundred and ten recoveries of which 45 or 40.5% came from localities within 15 miles of the station; first year, 27; second year, 15; 1 each in fourth, fifth, and sixth years. Station 3. Forty-two recoveries of which 18 or 42.8% came from localities within 10 miles of the station; first year, 11; second year, 5; 1 each in fifth and tenth years.

Furthermore there is a relatively large amount of evidence suggesting that units of population remain together on the wintering ground in successive years and, presumably, visit the same localities to nest in summer. A total of 32 records has been made in which a male and female, or two males, or two females banded on the same day at the same place were recovered a year or more later, some couples on the same day at the same place, others in the

TABLE II

FREQUENCY OCCURRENCE OF IDENTIFIED FOOD ITEMS IN 218 MALLARD STOMACHS

| | | |
|---|---|---|
| Sockeye salmon, *Oncorhynchus nerka* | Eggs | 10 |
| Salmon, *Oncorhynchus* sp. | Bones, flesh | 2 |
| Unidentified fish (Pisces) | Bones | 1 |
| Leech, Hirudinea | Egg cases | 1 |
| Amphipod, unidentified marine form | | 1 |
| Amphipod, *Hyalella azteca* | | 2 |
| Shore crab, *Hemigrapsus* sp. | | 1 |
| Dragonflies (Odonata) | Nymph | 45 |
| Damsel flies (Odonata) | Nymph | 9 |
| Water boatmen, Corixidae | | 53 |
| Caddis, Trichoptera | Larva | 3 |
| Micro-trichoptera | Larva | 2 |
| Beetle (Coleoptera), unidentified terrestrial form | | 4 |
| Beetle (Gyrinidae) | | 5 |
| Beetle, unidentified aquatic form | Larva | 1 |
| Beetle, *Dytiscus* sp. | Larva | 1 |
| Crane fly (Tipulidae) | Larva | 1 |
| Fly (Diptera) | | 1 |
| Midge (Chironomidae) | Larva | 5 |
| Cricket (Orthoptera) | | 1 |
| Snails, unidentified marine forms | | 2 |
| Snails, *Littorina scutulata* | | 2 |
| Snails, unidentified freshwater forms | | 18 |
| Snails, *Planorbis* sp. | | 1 |
| Snails, *Limnea* sp. | | 1 |
| Clam, *Pisidium* sp. | | 1 |
| Bryozoa | Statoblasts | 3 |
| Marine algae | | 1 |
| Muskgrass, *Chara* sp. | Branches | 1 |
| Muskgrass, *Chara* sp. | Oospores | 4 |
| Filamentous algae, *Spirogyra* sp. | | 1 |
| Horsetail, *Equisetum* sp. | Roots | 1 |
| Bur-reed, *Sparganium* sp. | Seeds | 46 |
| Cat-tail, *Typha latifolia* | Seeds | 1 |
| Pondweeds, *Potamogeton heterophyllus* | Seeds | 7 |
| *Potamogeton pusillus* | Seeds | 9 |
| *Potamogeton foliosus* | Seeds | 27 |
| *Potamogeton foliosus* | Leaves | 3 |
| *Potamogeton pectinatus* | Leaves | 4 |
| *Potamogeton pectinatus* | Seeds | 71 |
| Ditch grass, *Ruppia occidentalis* | Seeds | 2 |
| Grass (Gramineae) | Leaves | 24 |
| Barnyard grass, *Echinochloa* sp. | Seeds | 2 |
| Wild oat, *Avena fatua* | Seeds | 41 |
| Cultivated oat, *Avena sativa* | Seeds | 3 |
| Wheat, *Triticum vulgare* | Seeds | 19 |
| Sedge, *Carex* sp. | Seeds | 12 |
| *Carex exsiccata* | Seeds | 4 |
| *Carex vesicaria* | Seeds | 1 |
| Bulrush, *Scirpus acutus* | Seeds | 106 |
| *Scirpus americanus* | Seeds | 1 |
| Spike rush, *Eleocharis palustris* | Seeds | 14 |
| *Eleocharis obtusa* | Seeds | 1 |
| Dock, *Rumex maritimus* | Fruits | 1 |
| Bindweed, *Polygonum convolvulus* | Seeds | 20 |
| Knotweed, *Polygonum aviculare* | Seeds | 3 |
| Smartweed, *Polygonum amphibium* or *Muhlenbergii* | Seeds | 18 |
| *Polygonum lapathafolium* | Seeds | 31 |
| *Polygonum hydropiper* | Seeds | 3 |

TABLE II—*Concluded*

FREQUENCY OCCURRENCE OF IDENTIFIED FOOD ITEMS IN 218 MALLARD STOMACHS—*Concluded*

| | | |
|---|---|---|
| Smartweed, *Polygonum acre* | Seeds | 2 |
| *Polygonum persicaria* | Seeds | 5 |
| *Polygonum hydropiperoides* | Seeds | 10 |
| Goosefoot, *Chenopodium* sp. | Seeds | 4 |
| Orach, *Atriplex* sp. | Seeds | 2 |
| Pond lily, *Nuphar polysephalum* | Seeds | 1 |
| Penny cress, *Thlaspi arvense* | Seeds | 4 |
| Ball mustard, *Nestia paniculata* | Seeds | 3 |
| Rose, *Rosa* sp. | Seeds | 1 |
| Water milfoil, *Myriophyllum spicatum* | Seeds | 9 |
| *Myriophyllum spicatum* | Leaves | 1 |
| Hornwort, *Ceratophyllum demersum* | Leaves | 2 |
| *Ceratophyllum demersum* | Seeds | 3 |
| Dogwood, *Cornus occidentalis* | Seeds | 1 |
| Buckbean, *Menyanthes trifoliata* | Seeds | 2 |
| Mint, *Mentha* sp. | Seeds | 1 |
| Bedstraw, *Galium* sp. | Seeds | 2 |

same general locality on approximately the same dates (Table XIV). When the chances operating against such dual recoveries are considered, the number of such cases is impressive. Therefore the conclusion that population units winter and migrate together and probably nest in the same locality, is inescapable.

Two recoveries of juvenals banded in the interior of British Columbia and recovered the same year at localities near the mouth of the Fraser River are of sufficient interest for inclusion here. The particulars are: juvenal, banded at Kleena Kleen, July 18, 1933, recovered at Douglas Island, October 28, 1933; juvenal, banded at Swan Lake, Peace River, June 24, 1941, recovered at Sea Island, December 6, 1941.

South of the Coastal Plain the concentration of mallards is less pronounced. In migration a wide dispersal from the eastern counties of Washington and Oregon to the outer coasts of these states is general (Table VI). The most important wintering ground, as indicated by banding recoveries, is an area adjacent to the Columbia River mouth. Sixteen current and 42 later recoveries represent this area. The remainder of the total 174 recoveries are from other widely separated localities.

Details of 18 recoveries are given in Table VII and several of these give some evidence of the time taken in travelling between the banding station and the place of recovery. One bird banded on November 2, 1937, was killed five days later at Klamath Falls, Oregon; another banded November 6, 1932, was killed in Multnomah County, Oregon, three days later. Detracting from the value of these records unfortunately is the fact that it cannot be known how long the bird had been on the scene of its recovery before

being shot. The conclusion reached through a study of these data is that a small but constant stream of migration flows south and east from the Coastal Plain. They suggest that this migration represents one or several populations distinct from those wintering in areas farther north.

There are a few recoveries that appear to be examples of a wandering, vagrant habit exhibited by a small percentage of the population. The particulars are:

| Banding station | Date banded | Locality where recovered | Date recovered | Distance and direction travelled |
|---|---|---|---|---|
| 1 | Nov. 7, 1933 | Squamish, B.C. | Nov. 8, 1933 | 70 miles N.W. |
| 1 | Nov. 9, 1928 | Liberty, Mo. | Dec. 18, 1928 | 1500 miles S.E. |
| 1 | Nov. 17, 1934 | Mara, B.C. | Dec. 30, 1934 | 170 miles N.E. |
| 1 | Nov. 17, 1934 | Yakima Co., Wash. | Dec. 16, 1934 | 185 miles S.E. |
| 3 | Oct. 3, 1932 | Yakima Co., Wash. | Dec. 4, 1932 | 195 miles S.E. |
| 3 | Nov. 27, 1932 | Great Falls, Mo. | Dec. 23, 1932 | 550 miles S.E. |
| Portland, Oregon | Sept. 24, 1928 | Mission, B.C. | Oct. 15, 1928 | 260 miles N. |

The extent of distribution north of the Coastal Plain is indicated by the following recoveries made in the second year after banding and in later years: Malaspina Inlet, January, 1935; Toba Inlet, December 27, 1941; Loughboro Inlet, December 16, 1934; Knight Inlet, January 12, 1936, February 10, 1934; Bond Sound, December 11, 1935; Moresby Island, November 28, 1935; Masset Inlet, December 23, 1934; Craig, Alaska, January 23, 1937. It may be said that field observations show that a much larger winter population exists north of the Coastal Plain than the small number of these recoveries would indicate.

*Spring Migration*

A migration northward along the coast and northeast into the interior of British Columbia, Alberta, Alaska, and Yukon Territory commences in late February, is at its height in March and continues through April. At this time flocks of transients are conspicuous on small lakes and sheltered bays of the sea along the Coastal Plain. The size of these gatherings is indicated by the following counts: Quamichan Lake, March 10, 1934—100; Boundary Bay, March 15, 1934—300 ±; Agassiz, March 29, 1935—250 ±; McGillivray Creek Game Reserve, March 30, 1935—300 ±; March 31, 1935—500 ±.

The only information available concerning points farther north refers to Port Hardy, north end of Vancouver Island, where a migratory movement has been observed between April 20 and May 10 (Allan Lyon, personal letter) and to McClinton Creek, Queen Charlotte Islands, where migrating flocks, numbering up to 65, were recorded during the last two weeks of April, 1935.

*Summer*

Following the spring departure of wintering flocks from the coast the residual population is relatively small and scattered. In British Columbia

the mallard nests from southern Vancouver Island to the Queen Charlotte Islands and from the Canada–United States boundary to Alaska. It is resident on the coast region in the sense that mallards are present at all times of the year. To what extent local nesting populations are sedentary and to

TABLE III

Number of mallards banded in British Columbia and total recoveries

| Banding periods | Number banded | | | Total recoveries | Recovery, % |
|---|---|---|---|---|---|
| | ♂ | ♀ | Totals | | |
| Station No. 1— | | | | | |
| 1928, Oct. 20 – Dec. 31 | | | 643 | 178 | 27.7 |
| 1930, Oct. 21 – Dec. 5 | 176 | 290 | 466 | 124 | 26.6 |
| 1931, Nov. 3 – Dec. 8 | 240 | 204 | 444 | 67 | 15.0 |
| 1932, Oct. 16 – Dec. 9 | 500 | 585 | 1085 | 292 | 26.9 |
| 1933, Mar. 29 – April 18 | 41 | 55 | 96 | | |
| 1933, Oct. 4 – Dec. 12 | 923 | 1489 | 2412 | 615 | 24.5 |
| 1934, Jan. 28 – Mar. 14 | 259 | 268 | 527 | | |
| 1934, Oct. 7 – Dec. 5 | 1280 | 1687 | 2967 | 674 | 19.2 |
| 1935, Mar. 5 – April 11 | 4 | 5 | 9 | | |
| 1935, Oct. 22 – Dec. 31 | 572 | 581 | 1153 | 251 | 21.6 |
| 1936, Jan. 18 – April 11 | 65 | 83 | 148 | | |
| 1936, Oct. 10 – Dec. 28 | 195 | 197 | 392 | 103 | 19.0 |
| 1937, Mar. 19 – April 4 | 75 | 79 | 154 | | |
| 1937, Oct. 31 – Dec. 12 | 251 | 287 | 538 | 126 | 18.2 |
| 1938, Nov. 24 – Dec. 31 | 385 | 431 | 816 | 130 | 15.9 |
| 1939, Jan. 1 – April 19 | 209 | 302 | 511 | | |
| 1939, Nov. 14 – Dec. 31 | 1066 | 902 | 1969 | 333 | 13.4 |
| 1940, Jan. 1 – Mar. 31 | 140 | 133 | 273 | 34 | 12.4 |
| | | | 14,602 | | |
| Station No. 2— | | | | | |
| 1933, Feb. – April | | | 310 | 52 | 16.7 |
| 1934, Feb. – April | | | 570 | 84 | 14.7 |
| 1935, Feb. – April | | | 438 | 27 | 6.1 |
| | | | 1318 | | |
| Station No. 3— | | | | | |
| 1932, Oct. 3 – Dec. 31 | | | 241 | 47 | 19.5 |
| 1933, Jan. 1 – Feb. 19 | | | 83 | | |
| 1933, Sept. 4 – Dec. 17 | | | 501 | 102 | 17.4 |
| 1934, Oct. 9 – Dec. 31 | | | 30 | 2 | 6.6 |
| 1935, Jan. 1 – Jan. 20 | | | 15 | 2 | 13.3 |
| | | | 869 | | |
| Station No. 4— | | | | | |
| 1931, Nov. | | | 48 | 7 | 14.6 |
| 1932, Nov. 1 – Nov. 20 | 73 | 62 | 135 | 35 | 25.9 |
| 1933, Oct. 30 – Nov. 9 | 47 | 15 | 62 | 26 | 41.9 |
| | | | 245 | | |
| Station No. 5— | | | | | |
| 1932, Aug. 14 – Oct. 6 | | | 143 | 35 | 24.4 |
| 1933, Aug. 30 – Oct. 20 | 110 | 108 | 218 | 41 | 18.8 |
| | | | 361 | | |
| Totals | 6611 | 7763 | 17,395 | 3387 | |
| | | | | Average, % | 19.4 |

what extent they are replaced in winter by transients from elsewhere is not known.

Concerning southern Vancouver Island there is some evidence in the form of banding data that suggests the existence of a strictly resident and sedentary population. This evidence is that all the 13 recoveries from a minor banding project at Elk Lake, during the period August to January in several years, were made within 30 miles of the place where banded. Of these 10 were recovered within a week to four months after banding; one was recovered after 11 months and two in the fifth year after banding.

A definite conclusion regarding the status of summer populations in the southern coast region is complicated by the following factor. Since the early settlement of the region many farmers have practised the domestication of wild mallards and for a long period also hunters propagated them for use as live decoys; so also the so-called call ducks and other strains of domestic mallards were crossed in captivity with wild stock. Through the years a great many birds of mixed strain were liberated and they seem to have bred with, and gradually been absorbed by, the wild stock. Certain populations of mixed stock established and resident on protected waters near urban centres constantly were being replenished by wild mallards and at the present time all have the characteristic appearance of the wild birds. They are tamed to fearlessness by frequent feeding but are not confined and make flights to and from the sea. In winter the flocks are joined by baldpate, canvas-back, and other ducks.

It seems likely that the domestication and subsequent liberation of wild mallard, the infusion of domestic strains, and the feeding of large numbers on protected areas and, formerly, on duck-hunting clubs has increased the local nesting population and to some extent at least has modified their seasonal movements. Nevertheless it can be asserted that the numbers of the resident coast population are relatively small, certainly not large enough to materially affect the conclusions summarized above concerning the movements of the large transient and winter populations.

## Interior Region

### *Spring Migration*

Spring observations in the Okanagan Valley over a period of years show that in early March flocks of wintering mallards break into smaller units, some to travel north, others to local nesting grounds. Somewhat later appear birds that have wintered along the coast; for the most part these come from points south of the Coastal Plain.

The interior plateaux of the Nicola, Kamloops, and Cariboo regions form a wide highway of migration and dispersal to the Peace River districts of British Columbia and Alberta, to the Chilcotin, and to nesting grounds in central and northern British Columbia, Alaska, and the Yukon. On this highway mingle flocks that have travelled from the coast by way of the Columbia–Okanagan as noted above, by the Fraser–Thompson, and by the

Harrison-Lillooet and Seton Lake systems. The 43 first spring recoveries of mallards banded on the Coastal Plain, Tables VIII and IX, indicate, with some degree of accuracy in respect of time, the northward progress of this migration. The following records are arranged from south to north: Lac La Hache, B.C., April 30, 1934; Horsefly, B.C., April 6, 1934; Woodpecker, B.C., April 21, 1934; Stuart Lake, B.C., April 26, 1934; Crooked River, B.C., April 14, 1934; Fort Fraser, B.C., April 15, 1934; Dawson Creek, B.C., April 30, 1936; Athabasca, Alta., May 9, 1934; Fort Vermilion, Alta., May 14, 1934; White Horse, Yukon, May 14, 1934; Galena, Alaska, May 21, 1934. The 33 later year recoveries, Table VIII, serve to confirm the above definition of the migration routes.

Some information on the spring migration is available from other sources. The earliest record for the species at Chezzacut Lake in the Chilcotin is March 22, 1941—2; it became common on April 1, 1941—100± (F. M. Shillaker, personal letter). At Francois Lake 1500± were counted on April 16, 1941 (J. Sugden, personal letter). In 1938 it was first seen at Tetana Lake on April 14 and became abundant on April 21 (6). The earliest record for Atlin is April 14, 1938 (7).

*Autumn Migration*

Usually by the end of September a general dispersal, influenced in some sections by the opening of the hunting season, has taken place. In the Cariboo region, where the extent of the feeding grounds is large, part of the population shifts to more remote feeding grounds but observations show that a definite southern movement is also general at this time. In the Okanagan Valley, where feeding grounds are of much less extent, a general exodus takes place following the opening of the hunting season. In the course of the ensuing few weeks a gradual influx of transients again builds up the population.

The following counts at Swan Lake, Okanagan, commencing 10 days after the opening of the hunting season in 1942, illustrate this point:

| Sept. 29 | Oct. 7 | Oct. 9 | Oct. 13 | Oct. 19 | Oct. 30 | Nov. 5 |
|---|---|---|---|---|---|---|
| 40 | 30 | 25 | 60 | 400 | 700± | 1000± |

Important data concerning the autumn migration were provided by the 76 recoveries from 361 mallards banded at Buffalo Lake. Evidence that individual mallards use the same migration route in successive years is afforded by four recoveries of birds banded in the autumn and recovered at or near the same place in later autumns. The particulars are:

| Date banded | Locality where recovered | Date recovered |
|---|---|---|
| September 21, 1932 | Lac La Hache | September 20, 1935 |
| September 21, 1932 | Buffalo Lake | October 13, 1937 |
| September 21, 1932 | Buffalo Lake | October 19, 1933 |
| October 6, 1933 | Buffalo Lake | September 28, 1934 |

The 55 first year autumn recoveries and the 21 recoveries in later years from mallards banded at this station, Table XI, show clearly that two migration routes are followed, one by the Columbia–Okanagan to wintering grounds chiefly along the Columbia River, the other by the Fraser–Thompson to the Coastal Plain (Table XII).

The 68 recoveries from 245 mallards banded at Vaseaux Lake in autumn are in two categories, the first derived from a population that apparently is resident in the Lower Okanagan Valley and discussed later, the second from a transient population (Table X).

Further evidence that mallards use the same migration route in successive years was afforded here by subsequent trap recoveries of three mallards banded at this station, the details being: one banded November 9, 1932, was recovered November 8, 1933; two banded November 10, 1932, were recovered November 7, 1933.

No first year recoveries, and only two in later years, were made on the Coastal Plain from mallards banded at this station, while nine were taken in the first autumn and winter at points to the south and east. The evidence is clear that the main route to the wintering ground is along the Columbia–Okanagan system. The particulars are given below.

| Date banded | Locality where recovered | Date recovered |
|---|---|---|
| November 7, 1932 | Spokane Co., Wash. | December 5, 1932 |
| 8, 1932 | Okanogan Co., Wash. | Winter 1932 |
| 15, 1931 | Chelan Co., Wash. | December 6, 1931 |
| 10, 1932 | Yakima Co., Wash. | November 23, 1932 |
| 16, 1931 | Walla Walla Co., Wash. | December 11, 1931 |
| 10, 1932 | Whitman Co., Wash. | December 8, 1932 |
| 12, 1932 | Polk Co., Oregon | November 24, 1932 |
| 12, 1932 | Columbia Co., Oregon | December 14, 1932 |
| 12, 1932 | Nez Perce Co., Idaho | Autumn 1932 |

The portion of British Columbia east of longitude 118° W., including the districts of east and west Kootenay, is represented by only five recoveries of banded mallards, one being taken in the first autumn after banding, the others in autumns of later years. They were recovered at widely separated points, viz., Revelstoke, Donald, Kootenay Lake, Grand Forks, and Radium Hot Springs. Mallards are fairly plentiful in the region and it might be expected that a large number originating here would have been banded on the Coastal Plain had this been their wintering ground or on the route of their migration. As such was not the case it may be inferred that the five recoveries representing this region are examples of individuals wandering from the normal course of migration. Possibly the mallards of the region are more closely associated with a population that nests in Alberta and migrates by a route east of the Rocky Mountains to a wintering ground on the Gulf of Mexico. This theory is strengthened by the fact that five mallards

banded at Moiese, Mont., were recovered in the region, two at Wynndel and one each at Sirdar, Kootenay Flats, and Golden (Table XV). Moiese is 170 airline miles southeast of Wynndel.

*Winter*

The presence of a winter population in the Lower Okanagan Valley has been mentioned. In a total of 68 recoveries from mallards banded at Vaseaux Lake 45, or 66.3%, were made locally, 18 in the current year and 27 in later years, 12 being taken in December when the normal migration season has ceased.

A winter population in the northern part of the Okanagan Valley has increased in size very considerably within the past decade during which time mallards have taken to feeding on the grain fields. This is discussed in the section dealing with food habits. In the winter of 1911, and in subsequent winters for approximately 10 years later, the majority left in late autumn when the small lakes and ponds froze over and only a small population, fluctuating in numbers from year to year, remained. These frequented open stretches of streams or gathered on the shore of Okanagan Lake where they fed upon vegetation that drifted on to the frozen shore. In the Okanagan Landing region during the winter of 1917–18 only eight were observed. No other precise counts for this period are available. In the winter of 1921–22 a flock estimated at 100 wintered on Shuswap Lake near Sicamous. This was a severe winter and although the birds were fed by local residents many of them died.

By 1931 it was observed in the Vernon district that the winter population was increasing in numbers as the following counts testify, viz.: Okanagan Landing, December 1, 1931, flocks totalling 100, December 30, 1932, 60; Coldstream, near Vernon, January 1, 1933, 150±; Okanagan Lake, north arm, December 19, 1935, 350±. The following five winters were exceptionally mild and it seems probable that the numbers of the wintering population increased but no definite information is available except for the winter of 1939–40. In this season large flocks estimated to total 2000 remained in the Kelowna and Vernon districts and a winter population also was reported from the Kamloops district.

Small winter populations are reported from Nelson in the west Kootenay and from Cranbrook in the east Kootenay. The most northerly interior record is for the San Jose River between Lac La Hache and Williams Lake where an estimated population of 50 wintered in 1939–40. This was reported to be the first instance of mallards remaining in the district through the winter.

*General Conclusions from Banding Data*

The recoveries of banded mallards show a wide summer dispersal of the species in British Columbia, Alberta, and Alaska and indicate the migration routes to these nesting grounds (Fig. 1). They show that a winter population is concentrated on a relatively small area along the lower Fraser River and Puget Sound, distributed with much less evidence of concentration through

all the western portion of Washington and Oregon, occupying portions of the eastern sections of these states and reaching its southern limit in north central California. The data indicate also that individual mallards migrate by the same routes to the same wintering grounds in successive years and that units of population maintain their association over a period of several years at least. They suggest that mallard populations in general are definite associations, nesting in the same locality, migrating together, and wintering together in the same areas from year to year.

TABLE IV

DISTRIBUTION OF TOTAL MALLARD RECOVERIES

| Locality where recovered | Number | Locality where recovered | Number |
|---|---|---|---|
| Alaska | 43 | Montana | 5 |
| Alberta | 68 | North Dakota | 1 |
| British Columbia | 2106 | Nevada | 1 |
| California | 11 | Oregon | 72 |
| Idaho | 9 | Wyoming | 1 |
| Illinois | 1 | Washington | 1055 |
| Manitoba | 1 | Yukon Territory | 10 |
| Missouri | 1 | Northwest Territory | 2 |
| | | TOTAL | 3387 |

## Reproduction

On the coast region mallards are paired in February or even earlier; copulation has been observed in January. They breed in their second year and there is no character apparent in life by which second year males can be distinguished from older males. Some associate in pairs so early as October; this is general in early spring prior to migration and flocks of transients composed chiefly of mated birds frequently have been observed. There is one record of male and female banded at Station 1 on February 12, 1934, and recovered the same spring at Fort Vermilion, Alta. Other records of male and female banded on the same day and recovered at or near the same place a year or more later, Table XIV, are taken to indicate a continued association of population units rather than of mated birds.

Courtship behaviour, as witnessed in March amongst a flock swimming on a small lake, consisted of vigorous bobbing by the male and a response in kind by the female. Occasionally a male made a quick forward movement and half rising from the water displayed the bright chestnut plumage of its breast. The courtship is of short duration and never reaches the excited pitch or the variety of movement that characterizes the courtship of some diving ducks. On the nesting grounds close companionship of a mated pair during the laying period is the rule but courtship has not been observed at this time.

Little information is available concerning the nesting of mallards in the coast region. In reference to southern Vancouver Island there is an exception-

ally early record of a brood of downy young, viz., Millstream, March 10, 1940 (I. McT. Cowan, personal letter). Another brood of downy young is recorded from "Extension Swamp" near Nanaimo, April 15, 1942 (A. L. Peake, personal letter).

Nesting is much later in northern parts of the coast region. At McClinton Creek, Queen Charlotte Islands, April 15–30, 1935, a population of 12 pairs were still associated in flocks during part of each day. So also was a population of approximately 12 pairs located along the Tlell River from a point near its mouth for a distance of five miles upstream. During the course of observation, May 4–14, 1935, these were seen in small flocks either in flight or resting on the stretches of shingle that sloped steeply to the river.

TABLE V

RECOVERIES OF MALLARDS, AUTUMN AND WINTER, ON COASTAL PLAIN, STATIONS 1, 2, 3

| Locality where recovered | Current recoveries | Later years | Locality where recovered | Current recoveries | Later years |
|---|---|---|---|---|---|
| British Columbia— | | | Washington Counties— | | |
| Mouth Fraser River | 183 | 103 | Whatcom | 164 | 97 |
| Sardis region | 640 | 189 | Skagit | 190 | 229 |
| Intermediate points | 225 | 85 | Snohomish | 29 | 70 |
| Pitt River region | 171 | 91 | San Juan | 1 | 8 |
| Harrison River region | 41 | 17 | Island | 14 | 19 |
| Vancouver Island | 17 | 61 | King | 11 | 38 |
| Gulf Islands | 1 | 7 | | | |
| | | | TOTALS | 1687 | 1014 |

In the southern Okanagan Valley nesting commences about the first week in April, in the Nicola and Cariboo districts it is at least two weeks later. The following observations illustrate the pattern of behaviour at this time. In the Nicola district on April 24, 1939, all the mallards observed were paired. On certain lakes where the shoreline is open, so that it could be examined in detail, mated pairs rested on the beaches or on the water close to them. The distance separating two pairs was in no instance less than 200 yd., some were at much greater distances apart. A total of 37 counted on three lakes, April 24, 1941, consisted of 13 pairs and 11 single males. The latter were assumed to be on their territories while their mates were on their nests. The term "territory" is used here to identify the pond, or portion of stream, or area on lake shore usually occupied by a breeding pair. It is their feeding, breeding, and resting place; no behaviour that might be interpreted as territory defense has been observed. Very often such territory may be a long distance from the nest which the male apparently never visits.

The population as observed in the Cariboo district, April 27, 1939, consisted exclusively of paired birds; two weeks later, May 10–12, some territories appeared to be occupied by both male and female for long periods during the day while others under observation were occupied by males only. Heavy

floods occurred in June of that year and many nests were destroyed in consequence, a condition that might explain the several instances of females accompanied by males in eclipse recorded in early July. It was not determined if these pairs were nesting. During the period April 15–23, 1941, nearly every pond contained one or more pairs. At this time also flocks of transients numbering up to 20 or 30 and usually about equally divided as to sex were passing through. So late as May 26 a few still associated in pairs but the majority of males had already left the females. The following year nesting was later, thus at Springhouse, Cariboo, in early June small numbers could be identified as breeding and up to June 12, pairs were seen together on their territories. Possibly the latter may have represented a second laying following destruction of the first clutch.

*Nesting*

Mallards nest in many types of habitat from the river bottoms of the lower Okanagan Valley to the sedge-swamps and ponds in the subalpine forest. The following descriptions of nests illustrate the variety of sites chosen.

Monte Lake, Okanagan, May 1, 1940. Habitat, dry, open hillside above small pond; site under spreading branch of Rocky Mountain juniper; nest of down and vegetable debris; 9 eggs.

Okanagan Landing, May 5, 1915. Habitat, creek bottom, partly meadow, partly wooded with deciduous trees and shrubbery; site, small sedge marsh; nest of down concealed by dead alder branch; 10 eggs advanced in incubation.

Okanagan Landing, May 8, 1911. Habitat, same; site, grassy swale 50 yd. from stream; nest a 10-in. depression lined with down and broken pieces of round-stem bulrush, concealed by dead weed stalks; 11 eggs on point of hatching.

Okanagan Landing, May 10, 1917. Habitat, small mountain pond; site, three feet from water in small marsh of round-stem bulrush; nest of down mixed with small pieces of rotted bulrush; 10 eggs.

Westwick Lake, May 20, 1942. Habitat, round-stem bulrush marsh in lake; site, centre of large bulrush clump of previous year's growth beside open channel and about 100 ft. from shore; nest of short pieces of round-stem bulrush, some of which covered the eggs, and a small quantity of down; 9 eggs.

Springhouse, May 22, 1942. Habitat, 50-yd.-wide belt of round-stem bulrush marsh encircling small lake; site, thick clump of bulrush containing the yellowish stems of the previous year and the more weathered stems of an earlier year; nest of down and small quantity bulrush stems; 5 eggs.

Lac La Hache, May 28, 1942. Habitat, dry, wooded slope above lake; site, under drooping branch of Douglas fir 50 ft. from shore; nest of down mixed with fir needles and dry leaves; 10 eggs.

In the Peace River district in 1938 Cowan found the mallard to be the most abundant nesting duck and estimated the population at Swan Lake to be 100 pairs. Nests with full clutches of eggs were found from May 9 to May 31. Some were located under brush piles, in grass tufts near brush,

## TABLE VI

RECOVERIES OF MALLARDS, AUTUMN AND WINTER, SOUTH, EAST, AND WEST OF COASTAL PLAIN, STATIONS 1, 2, 3

| Locality where recovered | Current and first year | Later years | Locality where recovered | Current and first year | Later years |
|---|---|---|---|---|---|
| Western Washington Counties— | | | Eastern Washington Counties— | | |
| Clallam | 9 | 17 | Okanogan | | 1 |
| Jefferson | | 4 | Chelan | | 2 |
| Kitsap | 1 | 2 | Kittitas | | 3 |
| Mason | 1 | 3 | Yakima | 1 | 15 |
| Grays Harbour | 1 | 15 | Klickitat | | 2 |
| Pierce | 4 | 13 | Stevens | | 3 |
| Thurston | 1 | 8 | Spokane | 1 | 2 |
| Lewis | 3 | | Lincoln | | 2 |
| Pacific | 1 | 2 | Whitman | | 5 |
| Wahkiakum | 1 | | Walla Walla | | 2 |
| Cowlitz | 1 | 5 | | | |
| Clark | 3 | 8 | Eastern Oregon Counties— | | |
| | | | Klamath | 1 | |
| Western Oregon Counties— | | | Umatilla | | 5 |
| Clatsop | 2 | 5 | Lake | | 1 |
| Columbia | 4 | 11 | Union | | 1 |
| Washington | 1 | | | | |
| Multnomah | 3 | 11 | Idaho State | | 8 |
| Yamhill | 2 | 2 | California | | 8 |
| Clackamas | | 1 | Wyoming | | 1 |
| Marion | | 4 | Montana | 1 | 3 |
| Polk | 1 | 1 | North Dakota | | 1 |
| Linn | 1 | 2 | Illinois | | 1 |
| Benton | | 1 | Manitoba | | 1 |
| Lane | 3 | | Missouri | 1 | |
| Coos | | 4 | | | |
| | | | TOTALS | 48 | 184 |

in open meadows, and at distances from water varying from six feet to almost two miles (1).

In the early part of the incubation period females leave the nest to bathe and feed once each day; usually the pond, or lake, or stream visited is the one on which mating had taken place earlier. At Elliot Lake, June 28, 1941, a female flew down hill over the tree tops and planed to the lake on down-curved wings. Evidently she came from a nest some considerable distance away. On the water she splashed with her wings, stood up and shook her wings then started to swim across the small lake. Every few minutes she dived, remained under several seconds and upon emerging splashed the water with her wings, shook them vigorously then dived again.

*Survival of Young*

Mallards hide their downy young very effectively and at an early age they are seen less often on the open water of ponds and lakes than are the young of other pond ducks. A great part of their early life is spent in thick grass cover, in brush thickets, and other places of concealment. If disturbed from such

situations the female may flush, fly a short distance, then drop to cover again while the young remain hidden.

The earliest records for young are: "Deadman's Lake" near Oliver, Okanagan, May 8, 1928, downy young; Rawlings Lake, May 28, 1922, brood approximately one week old; Lac La Hache, June 1, 1942, downy young; Swan Lake, Peace River, May 27, 1938, downy young (1). The latest record is Horse Lake, August 18, 1937, half-grown young.

The following are the earliest records of flying young: Swan Lake, Okanagan, July 11, 1932; 143 Mile, Cariboo, July 22, 1938; 102 Mile, Cariboo, July 23, 1938; Riske Creek, August 2, 1937. By the second week of August a large proportion of the season's increase has reached the flying stage.

The mortality in young appears to be less than in the young of other duck species. The average brood size in the Cariboo district is tabulated below. First figure = number of broods counted; second figure = average number of young in brood.

| | June | | July | | August | |
|---|---|---|---|---|---|---|
| 1936 | | | 5 | 5.8 | 7 | 5.8 |
| 1937 | | | 9 | 5.5 | 9 | 6.2 |
| 1938 | | | 38 | 6.5 | 2 | 6.5 |
| 1939 | | | 8 | 5 | | |
| 1940 | 4 | 6 | | | | |
| 1942 | 2 | 5.5 | | | | |

*Behaviour of Females and Young*

Female mallards vigorously defend their young; the following observations show the variation of behaviour in this endeavour. Near Okanagan Landing on July 7, 1916, a female that was leading her brood across a grassy knoll between two ponds walked into the nearest one where she relaxed on the surface with outspread wings and neck outstretched on the water. In this position she struggled over the surface for a short distance then sank back as if exhausted. She repeated this action several times then flew to the adjacent pond where later she was discovered in the marginal brush with her half-grown young.

At Rawlings Lake, May 28, 1922, a female rushed down a steep, wooded bank that rises from the lake shore, followed by a number of small young that tumbled over each obstruction encountered. She swam out on the lake for 20 yd. or so, accompanied by a portion of the brood, then circled back to the shore half out of the water and beating the surface with her wings. She did this four times and on each occasion found one of the lagging young. After all the young had reached the water she led them toward the centre of the lake.

At Bridge Creek on July 17, 1937, a female was seen leading seven half-grown young into the marginal sedges. After they had disappeared in this

cover she swam out in front of a passing canoe and made a series of dives accompanied by much splashing, one dive following another in quick succession as she proceeded up stream.

On July 1, 1938, at Exeter Lake, Cariboo, two female mallards, accompanied by two quarter-grown young, were swimming along at the edge of the shoreward rushes. A few minutes later the young swam into the marsh, where no doubt the remaining members of the broods were concealed, and the two adult females joined a female ring-necked duck, *Nyroca collaris*, that was flapping over the water in front of her brood of seven small young. All three females proceeded to act in the same manner. They pushed themselves along the surface thrashing the water with their wings, sometimes in advance of, sometimes making a complete circle about the running brood. Somewhat later another female mallard suddenly rose from the edge of a *Carex* marsh, where probably her brood was hiding, then quickly dropped to the water again in front of the observer's canoe. She swam ahead for 20 yd. or so, wings churning the water and head submerged so that only her back was visible, then rose and making a wide circle flew back to the marsh.

At 105 Mile Lake, June 16, 1942, a female mallard lay partly submerged and motionless on the water near the outer edge of a round-stem bulrush marsh. When approached by a canoe to a distance of 15 ft. she flapped out from the marsh moving in this manner for about 30 yd. then taking flight. She alighted 300 yd. or so from the shore, rested there for a short time then made a series of short flights sometimes flapping along the surface for a short distance after alighting. The brood, undoubtedly concealed in the rushes, was not seen.

*Behaviour of Postbreeding Males*

Postbreeding males, still in full breeding plumage, commence to flock soon after incubation has begun and territorial segregation then ceases. One instance of a male accompanying a female with downy young—"Deadman's Lake", May 28, 1928— is the only exception noted and this may have been, and probably was, a fortuitous association. An instance of three males remaining together all day at Springhouse, Cariboo, May 21, 1942, represents the earliest date upon which postbreeding association of males came under observation. Three females, believed to have been mated with these particular males, were incubating eggs in the vicinity at this time and so far as could be learned had ceased visiting their respective mates. By May 28 the original band of three males had increased to 11. Other examples of postbreeding males in full breeding plumage are: 74 Mile, Cariboo, May 26, 1941—30; 103 Mile Lake, Cariboo, May 26, 1941—20; Westwick Lake, May 30, 1941—35; Swan Lake, Okanagan, June 4, 1938—38; 70 Mile, Cariboo, June 7, 1937—19.

After several weeks, spent usually on the more open waters, the males commence to frequent areas provided with dense cover, such as brush-fringed ponds and small lakes, willow swamps, and marshes of round-stem bulrush.

Although some such places may contain large numbers of males they no longer associate in flocks; they have become shy and it is difficult to flush them. Round-stem bulrush marshes are favoured resorts at this time and show evidence of occupation even if the birds are not seen. Thus at Westwick Lake in early June, 1941, practically all the muskrat houses, old grebes' nests, piles of rotted vegetation, and other small resting places in the marsh were strewn with mallard feathers, chiefly those from flank and chest but including also wing primaries and secondaries. A number of moulting mallards were found here at this time. When alarmed those still capable of flight rose heavily and after flying a short distance dropped into the rushes again while those that were flightless could be heard and occasionally seen in the thick cover. Sometimes moulting males are discovered in situations where the cover affords less effective concealment. Thus at Horse Lake, July 24, 1936, one swam through an open patch of rushes in deep water in advance of a moving canoe. It made several unsuccessful attempts to rise, then finally did so and flew low over the water for half a mile or so. The earliest date for a male in full eclipse, or in nearly full eclipse, is June 9, 1930, when one, with wing feathers partially moulted, was flushed from the marsh at Swan Lake, Okanagan.

TABLE VII

SELECTED CURRENT RECOVERIES OF MALLARDS SOUTH, EAST, AND WEST OF COASTAL PLAIN, STATION 1

| Date banded | Locality where recovered | Date recovered |
|---|---|---|
| Nov. 9, 1928 | Columbia Co., Oregon | Nov. 18, 1928 |
| Nov. 4, 1930 | Linn Co., Oregon | Nov. 23, 1930 |
| Nov. 9, 1931 | Pierce Co., Wash. | Nov. 16, 1931 |
| Nov. 11, 1931 | Polk Co., Oregon | Dec. 13, 1931 |
| Oct. 19, 1932 | Pierce Co., Wash. | Oct. 23, 1932 |
| Nov. 6, 1932 | Multnomah Co., Oregon | Nov. 9, 1932 |
| Nov. 8, 1933 | Clallam Co., Wash. | Nov. 26, 1933 |
| Dec. 10, 1933 | Clallam Co., Wash. | Dec. 15, 1933 |
| Oct. 21, 1933 | Grays Hbr. Co., Wash. | Nov. 8, 1933 |
| Nov. 8, 1933 | Multnomah Co., Oregon | Nov. 25, 1933 |
| Oct. 29, 1934 | Cowlitz Co., Wash. | Nov. 11, 1934 |
| Nov. 3, 1934 | Clatsop Co., Oregon | Nov. 23, 1934 |
| Nov. 3, 1934 | Columbia Co., Oregon | Nov. 18, 1934 |
| Nov. 22, 1934 | Clallam Co., Wash. | Dec. 22, 1934 |
| Oct. 23, 1936 | Wahkiakum Co., Wash. | Nov. 5, 1936 |
| Oct. 25, 1936 | Lane Co., Oregon | Nov. 8, 1936 |
| Nov. 2, 1937 | Klamath Co., Wash. | Nov. 7, 1937 |
| Nov. 2, 1937 | Kitsap Co., Wash. | Dec. 12, 1937 |

In early July males that have renewed their flight feathers commence to appear on the more open waters. July 1, 1938, is the earliest date for such in the Cariboo district. In that year two other early appearances were recorded at Williams Lake on July 4 and July 5. On July 11, 1940, seven single birds were flushed from the marshes on Tatton Lake. Later in the month the males again commence to flock. Examples showing the size of these gather-

ings are: McKinley Lake, July 20, 1938—200±; Mirage Lake, August 1, 1938—70; 150 Mile Lake, August 2, 1937—20.

As the summer passes flocks of flying eclipse males are joined by females and young. The following counts are typical of these mixed associations as they occur in the Cariboo district: Buffalo Lake, August 7, 1936—190±; 103 Mile Lake, August 8, 1936—100±; Cummings Lake, August 10, 1938—300±; 103 Mile Lake, August 20, 1937—200±.

*Summary*

It can be said in brief summary that in the more southern districts of interior British Columbia mallards are mated in March, they associate generally in pairs during the laying period in April and May but sometimes assemble in small flocks. After incubation begins the males, still in full breeding plumage, gather in flocks; subsequently they disperse and go into eclipse. When the flight feathers are renewed a large percentage again assemble in flocks while the remainder remain solitary. Later some of these flocks are joined by females and flying young.

## Restrictive Factors

The mallard is the duck most highly regarded as an object of sport and for food, consequently the hunting pressure is greater on this species than on other ducks. In some localities hunters attempt with frequent success to restrict their daily bag to mallards and if possible to males only. The males, because of their larger size are more sought after than the females; nevertheless on the basis of banding records the number of females shot is greater than the number of males. In a total of 2576 banded birds shot, 1299 were female and 1277 male.

Lead poisoning, caused by the ingestion of lead shot, is a restrictive factor of unknown proportion. It seldom is apparent in the interior of the province but is of common occurrence in the lower Fraser Valley where hunting is more concentrated and hunting grounds contain great quantities of shot that have accumulated through many years. Lead poisoning is most evident in dry years when low water has exposed areas of mud flat and lake bottom that at other times, because of the depth of water that covers them, are not accessible to mallards. The stomachs of 12 mallards in a total of 90 shot in this region during November, 1934, contained shot. Whether or not these had the symptoms of lead poisoning was not determined as the bodies were not available for examination. There is some evidence that mallards may develop resistance to lead poisoning and this appeared to be so in three from Pitt Meadows each of which contained shot in the stomach. In two the pellets were worn down to disks which indicated that the birds had been absorbing an amount of lead that in most ducks would constitute a lethal dose. All were in normal condition and showed none of the symptoms associated with lead poisoning.

The flooding of mallard nests in spring and, conversely, summer droughts that restrict food on the nesting grounds are factors that operate unfavourably. So also is the tendency of mallards to winter in districts where sub-zero temperature greatly restricts the food supply.

TABLE VIII

RECOVERIES OF TRANSIENT MALLARDS NORTH OF COASTAL PLAIN, STATIONS 1, 2, 3

| Locality where recovered | Number of recoveries | | | |
|---|---|---|---|---|
| | First spring | Later years | First autumn | Later years |
| British Columbia— | | | | |
| Mainland coast | | | 10 | 3 |
| Nicola region | 1 | | 8 | 7 |
| Kamloops region | | | 8 | 5 |
| Okanagan region | | | 4 | 6 |
| Cariboo region | 5 | 3 | 19 | 16 |
| Chilcotin region | 3 | 5 | 7 | 7 |
| Central region | 8 | 9 | 12 | 15 |
| Peace River region | 2 | | 5 | 2 |
| Northern region | 2 | 1 | | 1 |
| Grand Forks | | | | 1 |
| West Kootenay | | | | 1 |
| Revelstoke | | | | 1 |
| East Kootenay | | | 1 | |
| Donald | | | | 1 |
| Alberta— | | | | |
| Southern region | | | 4 | 4 |
| Central region | 2 | 1 | 7 | 1 |
| Peace River region | | 3 | 18 | 12 |
| Northern region | 5 | 4 | 6 | 1 |
| Yukon Territory | 5 | 1 | | 4 |
| Northwest Territories | 1 | | 1 | |
| Alaska— | | | | |
| Eastern region | 2 | 1 | 8 | 1 |
| Western region | 3 | 2 | 7 | 1 |
| Interior region | 4 | 3 | 2 | 8 |
| TOTALS | 43 | 33 | 127 | 98 |

Few instances of predation have been observed. In the Okanagan Valley, December 19, 1935, a gyrfalcon, *Falco rusticolus*, was shot while it was in pursuit of a female mallard. Examination of the falcon's crop showed it recently had eaten parts of a mallard. Near the same place on December 19, 1935, a goshawk, *Astur atricapillus*, was watched in an unsuccessful attempt to capture a mallard out of a large flock that circled about a stubble field. At White Horse Lake, July 27, 1938, the remains of a male mallard in eclipse plumage, lying on a flattened tussock of *Carex* on the muskeg shore, was believed to represent predation by a horned owl, *Bubo virginianus*.

The destruction of mallards' eggs by crows is a probable restrictive factor about which little is known. Concerning mallards of the Peace River district

Cowan reports that in 1938 they suffered heavily from this cause (1). Only once has destruction of mallard eggs by crows been observed by the writer and this was of an unusual nature. At Monte Lake, Okanagan, on May 1, 1940, a female mallard was flushed from a nest, well concealed under the branches of a Rocky Mountain juniper and containing 12 eggs. On May 9, three eggs lay on the ground a foot or so from the nest and from each the contents had been removed through a puncture in the side—undoubtedly the work of a crow. The remaining nine eggs were cold, the nest disarranged and swarms of red ants fed on the liquid that covered both the punctured eggs and those in the nest. The female was not seen and it was assumed she had deserted. On May 13, she was again on the nest which now contained only seven eggs. The nest had been remade, the eggs were half-hidden in down, and all traces of broken eggs and egg debris had disappeared.

In spite of a high degree of hunting pressure, and whatever other restrictive factors may operate, the recuperative power of the species is such that populations maintain their numbers and under extra favourable conditions increase. Because of its adaptibility in the matter of food and nesting requirements it has on the whole thrived under agricultural expansion in British Columbia. While in some areas drainage and subsequent cultivation have destroyed the source of one food supply, another of a different type in the form of grain, grasses, and weed seeds has taken its place. To this the species quickly adapted itself as it has done also to a changed type of cover. The clearing and subsequent cultivation of brush lands has produced similar results elsewhere. Most conspicuous, however, is the modification brought about in the interior of the province by the replacement of grasslands by grain fields thus providing an additional and highly nutritious type of food and a higher population potential.

## Sex Ratio

A total of 13,959 mallards for which sex records are available was banded at Station 1 during the period 1928–40 (Table III). Of these 6381, or 45.7%, were male, and 7578, or 54.3%, female. The number of females exceeded the number of males in each banding period except those of November–December, 1931, and November, 1939–March, 1940, when the reverse was the case. Banding recoveries show that more females are shot than males; in a 12-yr. period the numbers recorded were 1299 females and 1277 males. Thus hunting probably is not a factor in the sexual unbalance suggested by these figures.

## Food and Feeding Habits

### Coast Region

During autumn and winter the feeding grounds of one mallard population in the lower Fraser Valley is centred about the hay meadows and cultivated fields and the drainage ditches, sloughs, and swamps of this habitat. Food in the stomachs of specimens collected in this region was composed exclusively

of seeds of native plants and introduced weeds, grain and miscellaneous vegetation including a large percentage of grass leaves and fibres. In the Pitt Meadows the seeds of smartweed, *Polygonum hydropiper*, and other members of the Polygonaceae are eaten in large quantities and this diet is said to impart a distinctive flavour to their flesh. Another population feeds in the salt marshes and on tidal flats; stomachs from specimens taken in this habitat contained a variety of small marine animals, together with marine algae and seeds of various plants. A third population follows the spawning runs of salmon, which continue from October to January, and feeds exclusively on salmon eggs and salmon flesh.

TABLE IX

SELECTED RECOVERIES OF MALLARDS, FIRST SPRING, STATIONS 1, 2, 3

| Date banded | Locality where recovered | Date recovered |
|---|---|---|
| Dec. 7, 1938 | Lower Nicola, B.C. | June 5, 1939 |
| Feb. 12, 1934 | Lac La Hache, B.C. | April 30, 1934 |
| Feb. 25, 1934 | Horsefly, B.C. | April 6, 1934 |
| Feb. 1, 1934 | Horsefly, B.C. | May 4, 1934 |
| Feb. 25, 1934 | Woodpecker, B.C. | April 21, 1934 |
| Nov. 3, 1932 | Baker Creek, Quesnel, B.C. | April 27, 1932 |
| Jan. 28, 1934 | Kleena Kleen, B.C. | Spring, 1934 |
| Nov. 11, 1933 | Alexis Creek, B.C. | Spring, 1934 |
| Feb. 20, 1934 | Stuart Lake, B.C. | April 26, 1934 |
| Nov. 11, 1932 | Stuart Lake, B.C. | May 22, 1933 |
| Nov. 19, 1933 | Crooked River, B.C. | April 14, 1934 |
| Feb. 20, 1934 | Telkwa, B.C. | May 6, 1934 |
| Feb. 19, 1934 | Fort Fraser, B.C. | April 15, 1934 |
| Mar. 4, 1939 | Ootsa Lake, B.C. | April 15, 1939 |
| Jan. 9, 1936 | Dawson Creek, B.C. | April 30, 1936 |
| Dec. 23, 1939 | Moberly Lake, B.C. | April 14, 1940 |
| Dec. 27, 1935 | McDames Creek, B.C. | June, 1936 |
| Mar. 14, 1933 | Tp. 62, R. 12, W.4, Alta. | Spring, 1933 |
| April 13, 1939 | Mount Valley, Alta. | April, 1939 |
| Feb. 12, 1934 | Fort Vermilion, Alta. | May 14, 1934 |
| Feb. 12, 1934 | Fort Vermilion, Alta. | Spring, 1934 |
| Jan. 6, 1940 | Belloy, Alta. | April 10, 1940 |
| Nov. 18, 1933 | Athabasca, Alta. | May 9, 1934 |
| Mar. 10, 1934 | White Horse, Yukon | May 2, 1934 |
| Oct. 21, 1933 | White Horse, Yukon | May 15, 1934 |
| Nov. 13, 1934 | Carmacks, Yukon | May 10, 1935 |
| Oct. 26, 1932 | Kloo Lake, Yukon | May 10, 1933 |
| Dec. 15, 1938 | Liard River, N.W.T. | May 10, 1939 |
| Mar. 10, 1934 | Kwiguk, Alaska | May 21, 1934 |
| April 17, 1934 | Galena, Alaska | May 21, 1934 |
| Feb. 17, 1934 | Fort Yukon, Alaska | May 25, 1934 |
| Feb. 17, 1934 | Fort Yukon, Alaska | May 25, 1934 |
| Nov. 19, 1933 | Eagle, Alaska | May 2, 1934 |
| Nov. 19, 1933 | Nushagak, Alaska | April 1, 1934 |
| Dec. 13, 1935 | Yukutat, Alaska | May 16, 1936 |

In some localities such as Boundary Bay and the mouth of the Fraser River the birds congregate on the sea in the daytime and visit the fields to feed in morning and evening. After the shooting season has been in progress for a short time night-feeding becomes general and the evening flight does not

commence until the approach of darkness. This applies also at Pitt Lake and at other points along the Fraser River some distance inland where mallards concentrate in daytime. There is no evidence, however, that the population that uses the sea as a resting place feeds on the food available there. During spells of cold weather when surface water on the fields is frozen the population inhabiting the littoral is increased by an influx of individuals representing a part of the population that feeds on the fields, but so long as mild weather continues and small water areas remain open these populations continue to feed in these several separate habitats. In the analysis of stomach contents almost without exception the items present can be used to designate the general area where the specimen was taken. Only in one bird was a possible exception noted. In this, the stomach contained a large amount of vegetation and a fragment of organic material identified as salmon flesh. These findings would seem to afford further evidence that mallards associate in definite populations that are maintained from year to year.

On southern Vancouver Island a winter population makes daily flights from the sea to the flooded fields in the bottom lands. Here they find a variety of food including the seeds of many species of weeds and they have been seen feeding on potatoes that flooding had partially uncovered. In winters cold enough to freeze the water on the fields the birds remain close to the sea where they frequent bulrush and sedge marshes and the open tide flats. Here they find seeds of various kinds, mostly obtained on the ground or on the surface of the water, and on the tide flats they feed upon algae, molluscs, crustaceans, and other small animals exposed by a receding tide.

At Clements Creek, a tributary to Henderson Lake on the west coast of Vancouver Island, 4 to 15 mallards were observed daily during November and early December, 1922, feeding on salmon eggs. They fed by "dipping" in the shallow parts of the creek and after freshets had receded found many stranded eggs along the stream banks and in shallow pools in the brush back from the main stream channels (5). This habit is general on all the salmon streams of the coast. Mallards feed also on the flesh of spawned-out salmon and the diet of salmon eggs and salmon flesh, that usually is partly decomposed, imparts a rank flavour to the birds that consume it.

## Interior Region

In the northern Okanagan Valley during autumn one mallard population feeds almost exclusively in the grain fields. Here, as in the prairie provinces, feeding in the grain fields occurred seldom, if ever, during the early days of settlement. The habit developed slowly with the expansion of acreage sown to grain and later suddenly reached large proportions. In the Vernon district few mallards visited the stubble prior to 1930 but by the autumn of 1932 this manner of feeding had become a fixed habit. Flocks fed in the fields chiefly in the morning and evening, resting during part of the day on the open water of Okanagan Lake and to a lesser extent on Swan Lake. The following is characteristic of their behaviour.

From a hilltop north of Swan Lake on the evening of November 18, 1932, flocks of mallards, mostly invisible in a thick fog, were heard flying high in the air and alighting in a stubble field close to the lake. Occasionally a flock loomed up suddenly at close range but for the most part the birds were invisible. Overhead was heard the soft call of the males and less often, from flocks at high altitudes and flying very fast, a quick, sharp report like a clap of the hands, the source of which could not be determined. From the distant fields shrouded in fog came the ***kak, kak, kak*** sound of feeding birds. On the following morning flocks commenced to arrive in the fields before daylight; the whistling of wings and the tearing sound produced by masses of swiftly moving birds could be heard from all directions. Later in the early light a flock of 400 or more began circling the field high up, at times in a dense

TABLE X

RECOVERY OF MALLARDS BANDED AT STATION 4, VASEAUX LAKE

| Locality where recovered | Current and first year | Later years | Locality where recovered | Current and first year | Later years |
|---|---|---|---|---|---|
| Osoyoos to Penticton, B.C. | 18 | 27 | Grant Co., Wash. | | 1 |
| Naramata, B.C. | 1 | | Spokane Co., Wash. | 1 | |
| Kelowna, B.C. | 1 | 1 | Walla Walla Co., Wash. | 1 | |
| Mara, B.C. | 1 | | Whitman Co., Wash. | 1 | |
| Knouff Lake, B.C. | | 1 | Lincoln Co., Wash. | | 1 |
| Similkameen Valley, B.C. | 1 | 1 | Nez Perce Co., Idaho | 1 | |
| Coastal Plain, B.C. | | 1 | Columbia Co., Oregon | 1 | |
| Coastal Plain, Wash. | | 1 | Multnomah Co., Oregon | | 1 |
| Okanogan Co., Wash. | 1 | | Polk Co., Oregon | 1 | |
| Chelan Co., Wash. | 1 | | Yukon Territory | | 1 |
| Yakima Co., Wash. | 1 | 1 | TOTALS | 31 | 37 |

flock, then spreading out, then closing their ranks again as they wheeled, rose, or descended in fast flight. Flocks arrived and departed during the entire day but less often between 1:30 and 3:00 P.M. Large flocks, flying at great speed, would circle the fields numerous times in ever lessening circles, descending lower and lower with each circle, sometimes to disappear in the mist that hung low over the surrounding hills. Finally all alighted, some beside a flock of Canada geese that were feeding near the centre of the field a mile away, others at more distant points. It was estimated that 3500 visited the field during the day. Later in the same month a flock numbering 2000± was seen rising from this field. The birds first flew low over the stubble in a massed flock that gradually lengthened as they rose higher and higher on a westward course that finally took them over the ridge toward Okanagan Lake. In the late autumn of 1941 and of 1942 the number of mallards in the Vernon district was at least equal to and probably exceeded the numbers present 10 yr. earlier. A larger number frequented Swan Lake in daytime where they rested in large flocks on the open water, often associated with a raft of diving ducks, baldpates, and coots.

As stated earlier the autumn concentration of mallards in the northern Okanagan district, which had resulted from the development of the grain-eating habit, greatly increased the number of the wintering population. Recent mild winters, with light precipitation, provided a condition in which waste grain on the fields was always available in sufficient amounts to support them. Thus at Kelowna in the winter of 1939–40 the grain fields continued bare and some 2000 mallards remained there as did a large number in the Vernon district. The latter also obtained most of their food from the stubble fields but one flock numbering over 300 made daily visits to a farm where hogs were being raised and here they fed on oats that were thrown into the hog pens. These mallards became tamed to such an extent that they would not take flight when closely approached. In several other years, however, a sudden drop to subzero temperature, accompanied by snow, made grain in the fields inaccessible so that mallards were hard pressed for food and many did not survive.

Distinct from this concentrated population of grain-feeding mallards are other populations of smaller size that remain in the small streams, ponds, sloughs, and marshes throughout the district. At Swan Lake a number frequent the shoreline marshes and apparently do not mix with the grain-feeding population that spends part of the day on the open waters of this lake. When disturbed the latter leave the lake while those inhabiting the shoreline usually fly to another part of the marsh. The marsh-dwelling mallards feed chiefly on aquatic insect larvae and seeds of aquatic plants; specimens taken from this habitat rarely contain grain (4).

To what extent salmon eggs are consumed on the spawning streams of the interior is not known. The one mallard secured from Babine Lake contained sockeye salmon eggs and there is evidence that on Okanagan Lake the eggs of kokanee, *Salmo nerka kennerleyi*, are eaten. Here on numerous occasions in November flocks of mallards have been seen on the stony beaches along which kokanee had spawned a few weeks earlier. As no food other than dead kokanees and washed-out eggs was available it can be assumed that either or both were being eaten.

## Food Summaries

In the following section a summary is given of the food eaten by 118 mallards collected in the coast region and 100 collected in the interior of the province. The figure following the month indicates the number of specimens examined.

### Coast Region

*Fresh Water Habitat*

Colquitz, December, 1; Langford Lake, November, 1; Thetis Lake, December, 1; Cowichan River, November, 1; Mervale, December, 1; Quinsome Lake, January, 5; Henderson Lake, November, 6.

Salmon. One stomach from Henderson Lake contained a few salmon bones as the sole item. In another from Quinsome Lake salmon flesh composed 50% of the contents.

Salmon eggs. Seven specimens contained salmon eggs as the exclusive item; in two others this represented 20 and 80% respectively of the stomach contents. In quantity the number varied from two in one bird to 451 in another. Those in the specimens from Henderson Lake were chiefly sockeye salmon; those in specimens from Quinsome Lake were identified as probably chum salmon, *Oncorhynchus keta*.

Fishes. A stomach from Henderson Lake contained bones of a small fish not identified as to species.

Aquatic insects. Caddis larvae composed 99% of the food eaten by a specimen from Thetis Lake and was a minor percentage in another from Henderson Lake. A small quantity of insect debris was contained in a stomach from Cowichan River.

TABLE XI

RECOVERY OF MALLARDS BANDED AT STATION 5, BUFFALO LAKE

| Locality where recovered | Current and first year | Later years | Locality where recovered | Current and first year | Later years |
|---|---|---|---|---|---|
| Buffalo Lake region | 10 | 5 | Coastal Plain, British | | |
| Southern interior, British | | | Columbia | 3 | 1 |
| Columbia | 4 | 1 | Coastal Plain, Vancouver | | |
| Eastern Washington | | | Island | 4 | |
| Counties— | | | Coastal Plain, Washington | 6 | 5 |
| Okanogan | 1 | | Western Washington | | |
| Yakima | 2 | 2 | Counties— | | |
| Lincoln | 3 | | Pierce | 1 | |
| Walla Walla | 2 | | Mason | 1 | |
| Benton | 1 | | Lewis | | 2 |
| Eastern Oregon Counties— | | | Clark | 2 | |
| Klamath | 1 | | Grays Harbour | 2 | 1 |
| Umatilla | 1 | 1 | Western Oregon Counties— | | |
| Montana State | 1 | | Columbia | 2 | 1 |
| Nevada State | | 1 | Multnomah | 3 | |
| California State | 3 | | Tillamook | | 1 |
| | | | Benton | 2 | |
| | | | TOTALS | 55 | 21 |

Seeds. Except in one stomach from Langford Lake, where seeds were the exclusive item, this food represented only small percentages and occurred in a total of four stomachs. Species identified were *Potamogeton pectinatus*, *Sparganium* sp., *Menyanthes trifoliata*, and *Galium* sp.

Grain. Oak husks were present as a small percentage in two stomachs.

Miscellaneous vegetation. Plant debris, including in one specimen pieces of *Equisetum*, constituted 80%, 90%, and 100% of the contents of three and occurred as a minor item in one other stomach.

Lower Fraser Valley, November, 90.

Seeds. Seeds, chiefly of weeds and aquatic plants, were present in all but three of the 90 stomachs and in 48 composed 90 to 100% of the contents. The species of greatest importance in times of occurrence and volumetric

percentage was wild oat, *Avena fatua*, representing 90 to 100% of the food in 27 stomachs and occurring 41 times. Other seeds were present the number of times indicated, viz.; *Typha latifolia*, 1; *Potamogeton heterophyllus*, 1; *P. pusillus*, 1; *P. foliosus*, 25; *P. pectinatus*, 6; *Ceratophyllum demersum*, 2; *Echinochloa crusgalli*, 2; *Carex exsiccata*, 4; *Carex* sp., 5; *Scirpus americanus*, 1; *S. acutus*, 19; *Eleocharis palustris*, 12; *Polygonum convolvulus*, 19; *P. aviculare*, 1; *P. amphibium* or *Muhlenbergii*, 9; *P. lapathafolium*, 30; *P. hydropiper*, 2; *P. acre*, 2; *P. persicaria*, 5; *P. hydropiperoides*, 10; *Chenopodium* sp., 4; *Atriplex* sp., 1; *Thlaspi arvense*, 4; *Nestia peniculata*, 3; *Rosa* sp., 1; *Cornus occidentalis*, 1; *Mentha* sp., 3; *Galium* sp., 1.

Grain. Twelve stomachs contained wheat or oats representing 50% or more of the contents of three and small percentages in the remainder.

Miscellaneous vegetation. Grass leaves and unidentified vegetable matter was present in 41 and composed 90 to 100% of the total food in 21 stomachs.

Pitt Meadows, December, 6.

Seeds. Seeds, chiefly of aquatic plants, were the exclusive item in all specimens, *Carex vesicaria* being the species of first importance. Other seeds identified were *Eleocharis obtusa*, *Polygonum hydropiper*, and *Menyanthes trifoliata*.

*Salt Water Habitat*

Boundary Bay, November, 1, December, 1; Departure Bay, January, 2; Seal Island, January, 1.

Crustaceans. A small shore crab, *Hemigrapsus* sp., was the chief item in one, and a mixture of shore crab and amphipod debris composed 80% of the food in another stomach.

Mollusca. Small gastropods, including whole *Littorina scutulata* but represented chiefly by shell fragments of unidentified species, were present in three stomachs.

Algae. Pieces of unidentified algae constituted 95% and 50% of the food in two stomachs.

Seeds. Seeds of *Atriplex hastata* composed 40% of the food eaten by one specimen from Boundary Bay and seeds of *Eleocharis* sp. were present in another from Departure Bay.

## Interior Region

*Cariboo*

Lone Butte Lake, September, 1; 105 Mile Lake, September, 2; Tatton Lake, September, 1; Slough, 108 Mile, September, 1, October, 1; 122 Mile Creek, September, 3.

Amphipods. Amphipods composed 99% of the food in one specimen from 122 Mile Creek.

Aquatic insects. Dragonfly nymphs represented 10% of the total food in one stomach which contained also remains of crickets, members of the Orthoptera, and adult chironomids totalling 15%. In two stomachs were traces of corixids and in two others insect debris was a minor item.

Molluscs. Fragments of small gastropods were present in five stomachs, in one comprising 50%, in another 60%, of the total contents and in three others representing a minor item.

Miscellaneous animals. Bryozoan statoblasts were a minor item in one stomach.

Seeds. Seeds of aquatic plants were present in all but one of the nine stomachs from this region and comprised the sole item in one, the chief item in two, and an important constituent of the food in three others. The species most frequently represented were *Potamogeton pectinatus*, *P. pusillus*, and *Scirpus acutus*. Other genera represented were *Eleocharis*, *Myriophyllum*, *Sparganium*, and *Polygonum*.

Miscellaneous vegetation. Grass stems were the sole item in one and occurred in a second stomach. Rootlets and leaves of a *Potamogeton* was the only other identifiable item in three stomachs in which miscellaneous vegetation composed 15, 89, and 98% respectively of the total contents.

*Okanagan*

Cherry Creek, July, 1; Trinity Valley, October, 2; Vernon Commonage ponds, September, 2.

Aquatic insects. Dragonfly nymphs composed 6% in one and 3% in another stomach, both of which also contained three or more corixids and in one an adult beetle, *Dystiscus* sp.

Miscellaneous animals. One specimen contained five, another approximately 900, bryozoan statoblasts; in the latter this item represented 48% of the stomach contents.

Algae. Three stomachs contained *Chara* oospores, in one representing 2%, in another 5%, and in a third combined with *Chara* branches, 99% of the total contents.

Seeds. In one stomach 66 seeds of *Potamogeton pectinatus* composed 30%, and in another 120 seeds composed 35%, of the contents. Other seeds present in comparable bulk were *Potamogeton foliosus*, *P. pusillus*, *Sparganium* sp., *Nuphar polysephalum*, *Polygonum lapathafolium*, and *Ceratophyllum demersum*.

Swan Lake, September, 15, October, 45, November, 23, December, 2.

Aquatic insects. Aquatic insects were present in 65 stomachs, the most important in volumetric percentage being *Odonata* which was represented by 42 occurrences of dragonfly nymphs and 11 of damsel fly nymphs with a total percentage volume of 22.94%. In 16 birds the former composed 50% or more of the total stomach contents. Corixids, including *Arctocorixa laevigata* Uhl, were of next importance, occurring in 50 stomachs with a

total percentage volume of 18.45% and in 11 representing 50% or more of the food eaten. Other insects were represented the number of times indicated, viz.: micro-tricoptera, 2; fly larva, 1; chironomid larvae, 3; Cyrinidae, 4.

Coleoptera. Insect debris included in five birds the elytra of terrestrial beetles representing a minor percentage in each case.

Molluscs. Gastropods, represented by broken shells and debris and constituting small percentages usually less than 1%, occurred 13 times. A small bivalve, *Pisidium* sp., also was detected in one stomach.

Miscellaneous animals. There were two occurrences in this category, in one case several amphipods, in another a leech had been eaten.

TABLE XII

AUTUMN DISPERSAL OF MALLARDS FROM STATION 5, BUFFALO LAKE

| Date banded | Locality where recovered | Date recovered |
|---|---|---|
| Migration to Coastal Plain and Puget Sound | | |
| Sept. 22, 1932 | Chase, B.C. | Dec. 14, 1932 |
| Sept. 20, 1932 | Sardis Region, B.C. | Nov. 6, 1932 |
| Oct. 9, 1933 | Sardis Region, B.C. | Oct. 31, 1933 |
| Sept. 23, 1933 | Pitt River, B.C. | Dec. 31, 1933 |
| Sept. 19, 1933 | Barclay Sound, V.I., B.C. | Nov. 18, 1933 |
| Sept. 25, 1933 | Duncan, V.I., B.C. | Dec. 12, 1933 |
| Oct. 14, 1933 | Saanich, V.I., B.C. | Oct. 31, 1933 |
| Oct. 15, 1933 | Quamichan Lake, V.I., B.C. | Dec. 28, 1933 |
| Sept. 24, 1932 | Whatcom Co., Wash. | Dec. 3, 1932 |
| Aug. 30, 1932 | Skagit Co., Wash. | Nov. 20, 1932 |
| Sept. 24, 1932 | Skagit Co., Wash. | Nov. 27, 1932 |
| Oct. 15, 1933 | Skagit Co., Wash. | Dec. 6, 1933 |
| Sept. 25, 1933 | King Co., Wash. | Dec. 5, 1933 |
| Sept. 14, 1932 | Island Co., Wash. | Dec. 15, 1932 |
| Sept. 6, 1932 | Grays Hbr. Co., Wash. | Dec. 14, 1932 |
| Sept. 24, 1932 | Grays Hbr. Co., Wash. | Dec. 15, 1932 |
| Oct. 1, 1932 | Pierce Co., Wash. | Nov. 17, 1932 |
| Sept. 14, 1932 | Mason Co., Wash. | Oct. 29, 1932 |
| Inland migration by Columbia River | | |
| Sept. 14, 1933 | Kamloops, B.C. | Oct. 31, 1933 |
| Oct. 6, 1932 | Armstrong, B.C. | Dec. 21, 1932 |
| Sept. 13, 1932 | Vernon, B.C. | Nov. 27, 1932 |
| Sept. 10, 1932 | Okanogan Co., Wash. | Dec. 4, 1932 |
| Sept. 12, 1933 | Lincoln Co., Wash. | Oct. 25, 1933 |
| Sept. 30, 1933 | Lincoln Co., Wash. | Nov. 6, 1933 |
| Sept. 22, 1932 | Yakima Co., Wash. | Dec. 4, 1932 |
| Oct. 15, 1932 | Yakima Co., Wash. | Dec. 15, 1932 |
| Sept. 15, 1933 | Walla Walla Co., Wash. | Dec. 3, 1933 |
| Sept. 23, 1933 | Walla Walla Co., Wash. | Dec. 6, 1933 |
| Sept. 22, 1932 | Clark Co., Wash. | Nov. 13, 1932 |
| Sept. 30, 1933 | Clark Co., Wash. | Nov. 2, 1933 |
| Sept. 14, 1933 | Columbia Co., Wash. | Dec. 6, 1933 |
| Aug. 30, 1932 | Benton Co., Wash. | Nov. 6, 1932 |
| Sept. 23, 1933 | Multnomah Co., Wash. | Nov. 5, 1933 |
| Sept. 27, 1933 | Multnomah Co., Wash. | Nov. 12, 1933 |
| Sept. 19, 1933 | Los Benos, Calif. | Nov. 29, 1933 |
| Sept. 22, 1932 | Oakley, Calif. | Nov. 22, 1932 |
| Sept. 28, 1932 | Inyo Co., Calif. | Dec. 26, 1932 |

TABLE XIII

TRAP RECOVERIES OF BANDED MALLARDS

| Station banded | Date banded | Station where recovered | Dates recovered |
|---|---|---|---|
| 1 | Nov. 12, 1930 | 3 | Oct. 17, 1934 |
| 4 | Nov. 9, 1932 | 4 | Nov. 8, 1933 |
| 4 | Nov. 10, 1932 | 4 | Nov. 7, 1933 |
| 4 | Nov. 10, 1932 | 4 | Nov. 7, 1933 |
| 3 | Nov. 27, 1932 | 3 | Dec. 3, 1933 |
| 1 | Nov. 30, 1932 | 3 | Dec. 3, 1933 |
| 3 | Dec. 18, 1932 | 3 | Dec. 3, 1933 |
| 3 | Oct. 14, 1933 | 1 | Nov. 26, 1934 |
| 1 | Nov. 3, 1933 | 2 | April 15, 1934 |
| 1 | Nov. 19, 1933 | 1 | Nov. 26, 1933 |
| 1 | Dec. 7, 1933 | 1 | Jan. 16, 22, 1936 |
| 1 | Feb. 3, 1934 | 1 | Jan. 25, 1936 |
| 1 | Mar. 8, 1934 | 1 | Jan. 22, 1936 |
| 2 | April 18, 1934 | 1 | Nov. 27, 1934 |
| 1 | Jan. 14, 1936 | 1 | April 7, 1937 |
| 1 | Dec. 28, 1936 | 1 | Mar. 24, 1939 |
| 1 | Nov. 21, 1938 | 1 | Mar. 8, Dec. 25, 1939 |
| 1 | Nov. 24, 1938 | 1 | Dec. 9, 1939 |
| 1 | Dec. 7, 1938 | 1 | Dec. 5, 1939 |
| 1 | Dec. 12, 1938 | 1 | Nov. 17, Dec. 7, 1939 |
| 1 | Dec. 19, 1938 | 1 | Dec. 22, 1939 |
| 1 | Dec. 19, 1938 | 1 | Dec. 14, 1939 |
| 1 | Dec. 22, 1938 | 1 | Dec. 30, 1939 |
| 1 | Dec. 22, 1938 | 1 | Nov. 15, 1939 |
| 1 | Jan. 24, 1939 | 1 | Dec. 17, 1939, Jan. 7, 1940 |
| 1 | Jan. 27, 1939 | 1 | Mar. 15, 1940 |
| 1 | Feb. 1, 1939 | 1 | Jan. 5, 10, 1940 |
| 1 | Feb. 22, 1939 | 1 | Mar. 23, 1940 |
| 1 | Feb. 23, 1939 | 1 | April 8, 1939, Nov. 14, 1940 |
| 1 | Mar. 8, 1939 | 1 | Dec. 9, 1939, Mar. 15, 1940 |
| 1 | Dec. 24, 1939 | 1 | Dec. 29, 1941 |
| Big Suamico, Wis. | Oct. 31, 1929 | 3 | Oct. 21, 1934 |
| Oak Harbour, Wash. | Dec. 8, 1937 | 1 | Feb. 20, 23, 1939 |
| 1 | Nov. 18, 1932 | Stn. Athabasca, Alta. | May 9, 1934 |

Algae. One bird had eaten a small amount of filamentous algae, *Spirogyra* sp., another a small number of *Chara* oospores.

Seeds. Seeds of *Scirpus acutus* were present in all but four of the 85 stomachs examined and was the item of first importance in volumetric percentage. Some stomachs contained a small quantity, others up to 500 or more, and in 23, represented 50% or over of the food eaten. Seeds of *Potamogeton pectinatus* occurring 57 times, and in four stomachs representing 50% or more of the total contents, was the species of next importance. Other seeds were identified the number of times indicated, viz.: *Potamogeton foliosus*, 1; *P. pusillus*, 4; *P. heterophyllus*, 6; *Myriophyllum spicatum*, 3; *Carex* sp., 2; *Sparganium* sp., 1; *Rumex* sp., 1; *Polygonum amphibium*, or *Muhlenbergii*, 8; *P. aviculare*, 2; *P. convolvulus*, 1; *Ceratophyllum demersum*, 2.

Grain. Grain was not present in any specimens taken prior to 1942. In that year seven of the 47 specimens collected had eaten wheat, undoubtedly

TABLE XIV

CONTINUED ASSOCIATION OF MALLARDS

| Sex | Station banded | Date banded | Locality where recovered | Date recovered | |
|---|---|---|---|---|---|
| ♀ ♀ | 3 | Jan. 29, 1932 | Station 3 | Dec. 3, 1933 | Retrapped |
| ♂ ♂ | 4 | Nov. 10, 1932 | Station 4 | Nov. 7, 1933 | Retrapped |
| ♀ ♀ | 2 | Nov. 15, 1932 | Pitt Lake, B.C. | Oct. 22, Nov. 12, 1933 | Shot |
| ♂ ♀ | 3 | Dec. 18, 1932 | Station 3 | Dec. 3, 1933 | Retrapped |
| ♂ ♀ | 2 | Feb. 12, 1933 | Pitt River, B.C. | Oct. 15, Nov. 11, 1933 | Shot |
| ♂ ♀ | 2 | Mar. 9, 1933 | Pitt River, B.C. | Oct. 22, Oct. 29, 1933 | Shot |
| ♂ ♀ | 1 | Nov. 8, 1933 | Sumas, B.C. | Dec. 1, Dec. 10, 1934 | Shot |
| ♂ ♀ | 1 | Nov. 23, 1933 | Nicomen Island, B.C. | Oct. 22, Nov. 18, 1934 | Shot |
| ♂ ♀ | 2 | Feb. 12, 1934 | Ft. Vermilion, Alta. | ♂ May 14, ♀ "spring", 1934 | Shot |
| ♂ ♂ | 1 | Mar. 8, 1934 | Pitt River, B.C. | Nov. 8, Dec. 2, 1934 | Shot |
| ♀ ♀ | 2 | Mar. 28, 1934 | Pitt Lake, B.C. | Nov. 24, 1934 | Shot |
| ♀ ♀ | 1 | Nov. 24, 1935 | Harrison River, B.C. | Nov. 29, 1936 | Shot |
| ♂ ♀ | 1 | April 8, 1936 | Everett, Wash. | Nov. 10, 1940 | Shot |
| ♂ ♀ | 1 | Dec. 2, 1938 | Ladner, B.C. | Oct. 21, Nov. 17, 1939 | Shot |
| ♂ ♀ | 1 | Dec. 3, 1938 | Station 1 | ♂ Jan. 1, 1940, ♀ Dec. 10, 1939 | Retrapped |
| ♂ ♂ | 1 | Dec. 7, 1938 | Station 1 | Dec. 5, 1939, Dec. 24, 1939 | Retrapped |
| ♂ ♀ | 1 | Dec. 12, 1938 | Station 1 | ♂ Nov. 7, 1939, ♀ Dec. 7, 1939 | Retrapped |
| ♂ ♀ | 1 | Dec. 19, 1938 | Station 1 | ♂ Dec. 14, 1939, ♀ Dec. 22, 1939 | Retrapped |
| ♂ ♀ | 1 | Dec. 22, 1938 | Station 1 | ♂ Dec. 30, 1939, ♀ Nov. 15, 1939 | Retrapped |
| ♂ ♀ | 1 | Feb. 19, 1939 | Station 1 | Dec. 13, 1939 | Retrapped |
| ♂ ♀ | 1 | Feb. 20, 1939 | Station 1 | Dec. 23, 1939 | Retrapped |
| ♂ ♀ | 1 | Feb. 22, 1939 | Station 1 | ♂ Dec. 17, ♀ Dec. 30, 1939 | Retrapped |
| ♂ ♂ | 1 | Feb. 26, 1939 | Station 1 | Nov. 18, 1939 | Retrapped |
| ♂ ♂ | 1 | Mar. 8, 1939 | Station 1 | Jan. 2, Jan. 3, 1940 | Retrapped |
| ♂ ♀ | 1 | April 13, 1939 | Station 1 | ♂ Nov. 19, ♀ Dec. 30, 1939 | Retrapped |
| ♂ ♀ | 1 | Nov. 14, 1939 | Matsqui, B.C. | ♂ Nov. 6, ♀ Nov. 8, 1940 | Shot |
| ♂ ♀ | 1 | Nov. 15, 1939 | Chilliwack, B.C. | ♂ Nov. 13, ♀ Nov. 16, 1940 | Shot |
| ♂ ♀ | 1 | Dec. 9, 1939 | Chilliwack, B.C. | ♂ Nov. 24, ♀ Nov. 26, 1940 | Shot |
| ♂ ♀ | 1 | Dec. 10, 1939 | Station 1 | ♂ Mar. 21, 23, ♀ Mar. 3, 31, 1940 | Retrapped |
| ♂ ♀ | 1 | Dec. 17, 1939 | Station 1 | ♂ Mar. 13, ♀ Mar. 15, 1940 | Retrapped |
| ♂ ♂ | 1 | Dec. 23, 1939 | Station 1 | Feb. 4, Mar. 19, 1940 | Retrapped |
| ♂ ♀ | 1 | Dec. 25, 1939 | Station 1 | Nov. 24, 1940 | Retrapped |

taken from adjacent stubble fields. In three stomachs wheat kernels composed 99 or 100%, in two others 75%, and in another five per cent of the total contents. Another contained an equal quantity of oat and wheat husks. The amount varied from a few kernels to 75 cc.

Miscellaneous vegetation. In this category are included six occurrences of *Potamogeton* foliage, two of *Ceratophyllum demersum*, three of *Myriophyllum spicatum*, one of grass, and 23 of comminuted vegetable matter not further identified. Altogether this vegetation represented a total percentage volume of 12.59%.

Babine Lake, January, 1.

Salmon eggs. The single specimen contained 316 whole eggs of sockeye salmon, *Oncorhynchus nerka*, of which 120 were eyed, and a quantity of broken salmon egg-cases. Salmon egg material represented 95% of the food in a full stomach.

Aquatic insects. The remaining five per cent of food in this stomach was composed of 70± caddis larvae, three crane fly larvae, and three coleopterous larvae.

## Summary

At Henderson Lake and Quinsome Lake salmon eggs formed the chief food of 11 specimens; salmon flesh, an unidentified fish, caddis, and miscellaneous vegetation also had been eaten. The food eaten on other freshwater areas on Vancouver Island was composed of 62.4% vegetable matter, including seeds, grain, and plant material, 33.6% aquatic insects, and 4% mollusca. In the Lower Fraser Valley weed seeds and seeds of aquatic plants were of first and various grasses of second importance in the food eaten by 90 mallards. Specimens from Pitt Meadows had eaten seeds, largely *Carex*, exclusively. Mallards taken in a salt water habitat had eaten algae, small crustaceans, and molluscs.

In the Cariboo region vegetable matter constituted over 72% and various small animals, of which molluscs were first in importance, made up the remainder. At Swan Lake seeds of *Scirpus acutus* provided the largest single item in the 57% total of vegetation eaten by 85 mallards. The remainder consisted of miscellaneous seeds, foliage, and grain. Odonata and corixids with a combined percentage volume of over 41% were of next importance. Mollusca are a minor item of diet on this lake. Mallards from other lakes in the Okanagan had consumed vegetable matter, including *Chara* but largely composed of the seeds of aquatic plants, to the extent of over 80%, the balance being aquatic insects and small aquatic animals. One specimen from Babine Lake had eaten over 120 sockeye salmon eggs.

## Economic Status

From an economic standpoint the mallard is the most valuable of the duck species in British Columbia. Except on parts of the coast region where at certain times of the year a diet of salmon eggs and salmon flesh renders the flesh unpalatable it is the duck most highly prized by the hunter both for its game qualities and for the table.

In connection with its pursuit is involved a large number of industries and services including among other things the manufacture, distribution, and sale of motor cars, guns, ammunition, boats, and hunting equipment of various kinds; the transport of hunters and their equipment by rail, motor bus, and by other means of travel; the hotel and cabin-camp business, and the business of guiding.

Large sums of money are invested in hunters' equipment, in land used partly or exclusively for hunting and in numerous other enterprises each deriving part of its revenue from duck hunting, which in large degree means the hunting of mallards. The investment value of the latter cannot be assessed but the value of the investment in equipment may be estimated on the following basis. In 1941 a total of 39,932 hunting licenses were issued

to resident hunters in British Columbia. Assuming for the purpose of this discussion that each licensee is a duck hunter, actual or potential, and has spent a minimum sum of $50 on equipment the investment would total $1,996,600.

The sum distributed annually by duck hunters amongst various industries and services fluctuates considerably from year to year. On the basis of the license sales for 1941, and assuming that each of the licensees spent $25 in connection with his avocation, this item would total $998,300 for that year without the addition of the sum spent by non-resident hunters of whom 511 were licensed. The total of licensed hunters resident and non-resident was 40,443. From this source the province derived a revenue of $140,507.

TABLE XV

MALLARDS BANDED IN THE UNITED STATES, AND RECOVERED IN BRITISH COLUMBIA

| Banding station | Date banded | Locality where recovered | Date recovered |
|---|---|---|---|
| Sequim, Wash. | Jan. 3, 1926 | Sumas, B.C. | Dec. 9, 1926 |
| Oak Harbour, Wash. | Oct. 8, 1929 | Trapp Lake, B.C. | Oct. 13, 1937 |
| Sauvies Island, Oregon | Sept. 5, 1928 | Mission City, B.C. | Oct. 15, 1928 |
| Pilot Rock, Oregon | Jan. 25, 1934 | Chilako River, B.C. | April 15, 1938 |
| Stanfield, Oregon | Jan. 14, 1935 | Scuitto Lake, B.C. | Sept. 15, 1936 |
| Stanfield, Oregon | Jan. 17, 1935 | Torphy River, B.C. | Oct. 19, 1938 |
| Stanfield, Oregon | Jan. 17, 1935 | Wynndel, B.C. | Nov., 1938 |
| Stanfield, Oregon | Feb. 13, 1935 | Kamloops, B.C. | Sept. 24, 1939 |
| Burns, Oregon | Oct. 23, 1933 | Nation River, B.C. | Aug. 28, 1938 |
| Burns, Oregon | Nov. 25, 1935 | Fort McLeod, B.C. | Sept. 17, 1938 |
| Burns, Oregon | Nov. 3, 1936 | Nechako River, B.C. | Oct. 2, 1939 |
| Burns, Oregon | Nov. 3, 1936 | Kamloops, B.C. | Sept. 26, 1937 |
| Burns, Oregon | Oct. 21, 1938 | Nechako River, B.C. | Sept. 21, 1939 |
| Moiese, Mont. | Oct. 31, 1927 | Sirdar, B.C. | Nov. 25, 1929 |
| Moiese, Mont. | Nov. 7, 1927 | Wynndel, B.C. | Oct. 25, 1928 |
| Moiese, Mont. | Nov. 13, 1927 | Kootenay Flats, B.C. | Oct. 31, 1929 |
| Moiese, Mont. | Nov. 25, 1927 | Golden, B.C. | Autumn, 1929 |
| Moiese, Mont. | Sept. 24, 1928 | Wynndel, B.C. | Oct. 19, 1929 |
| Moiese, Mont. | Nov. 5, 1929 | Vernon, B.C. | Sept. 20, 1930 |
| Nampa, Idaho | Oct. 29, 1936 | Fort St. John, B.C. | Oct. 13, 1937 |
| Portage des Sioux, Mo. | Mar. 2, 1925 | Burnaby Lake, B.C. | Dec. 29, 1927 |

The above represents value in terms of invested capital and of revenue both direct and indirect. There is also a value in terms of food. Figures of the annual mallard kill are lacking but on the basis of only one mallard allotted to each two hunters the number shot would be 20,221. Each mallard represents at least one dollar of value in terms of food.

The feeding habits of the mallard have been the cause of an apparent conflict of interests between hunters on the one hand and farmers and fishing interests on the other. As pointed out earlier some mallard populations feed exclusively on salmon eggs and salmon flesh during several of the autumn and winter months. Whether or not consumption of the former is responsible for a reduction in the salmon population that might not otherwise take place has not, and probably never can be determined (4).

In British Columbia the consumption of grain by mallards has not reached the proportion that it has in the Prairie Provinces. In British Columbia grain crops usually are harvested prior to the arrival of any large mallard migration. Consequently most of the feeding is done on the stubble and involves slight if any loss to the farmer. No mallards feeding in standing grain or on grain in stook have been observed.

A habit of greater concern than feeding in the grain fields is that which leads to the destruction of young forage plants in the lower Fraser Valley. When fields are partly flooded, mallards, usually in company with other pond ducks, sometimes concentrate on a small area and pull up or otherwise destroy so many young clover plants or grasses that a bare patch in the field results.

The consumption of salmon eggs by mallards, or by other ducks, is a natural process that probably has persisted through countless generations of both ducks and salmon and quite conceivably is of benefit to the salmon as well as to the ducks. The subject is highly controversial but it seems reasonable to conclude that the consumption by various animals of dead salmon and surplus salmon eggs, is necessary to a healthy biota on any salmon stream. The relation between mallards and agriculture is in quite a different category and so far as known benefits only the ducks. It would be idle to attempt comparative valuations between the economic value of the mallard and of the salmon or of the mallard and the limited agricultural interests with which it is involved. It seems advisable, however, to stress the necessity for careful consideration of the economic value of the mallard when control of its numbers is contemplated on the grounds that it reduces agricultural crops or the supply of salmon.

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# THE VITAMIN $B_1$ CONTENT OF CANNED PORK[1]

By E. J. Reedman[2] and Leonard Buckby[3]


## Abstract

Canned pork of the type known as spiced luncheon meat was found to contain an appreciable amount of vitamin $B_1$ after the complete canning process. There were, however, losses of the original vitamin $B_1$ in the raw meat during the retorting process used for cooking and commercially sterilizing the product. These losses were 55.3%, 55.6%, and 41.9% of the original vitamin in three series of packs examined. It was possible to fortify 6-lb. export packs of canned pork with synthetic thiamin to a level equal to, or above, that of the natural vitamin in raw meat. The destruction of synthetic added vitamin was no greater than that of natural vitamin under the conditions of this study.


## Introduction

Raw lean pork muscle is known to contain an appreciable amount of vitamin $B_1$, and has been shown to be a richer source of this food factor than beef, veal, or poultry meat (1, 3, 5). Pork, in various forms, may thus constitute an important source of vitamin $B_1$ in human nutrition. However, the true value of a food must be assessed after preparation for consumption. Waisman and Elvehjem (5) found considerable destruction by the frying, broiling, or stewing of meats; losses approaching 50% were fairly common. A large amount of pork is now being canned for domestic consumption and for export. A study was made of the destruction of vitamin $B_1$ during the cooking and commercial sterilization of canned pork in order to establish data on the thiamin content of canned product, and to ascertain the destruction of natural and added synthetic vitamin $B_1$; but no attempt was made to survey the vitamin $B_1$ content of commercial canned pork.

## Material

The canned product studied was of the type known as spiced luncheon meat, packed in 6-lb. rectangular cans. A few analyses of raw pork meat and of canned luncheon meat from domestic 12-oz. packs are reported in Table I for purposes of comparison.

Canned luncheon meat is marketed as Canadian Spiced Pork and Canadian Spiced Ham, and is manufactured from lean pork trimmings and lean sow ham, respectively. The raw meat is trimmed to 20% or less fat, but varies somewhat in fat content. The raw meat is ground, vacuum mixed with curing salts and sugar, and cured at 38° F. for 48 hr. (or by a similar process). After curing, the product is again vacuum mixed, is stuffed raw into the cans,

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which are then vacuum closed and retorted to cook and commercially sterilize the meat. The only major source of destruction of vitamin $B_1$ is this heating process.

TABLE I

MOISTURE AND VITAMIN $B_1$ CONTENT OF SAMPLES

| Description of sample | No. of lots or cans analysed | Moisture, % | | Vitamin $B_1$, $\mu$gm./gm. (moisture-free basis) | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| 1. Raw lean chop pork, Series I | 3 | 66.5–70.1 | 69.2 | 31.5–63.8 | 52.0 |
| 2. Raw lean chop pork, Series II | 3 | 64.3–71.7 | 68.7 | 32.7–48.0 | 41.9 |
| 3. Domestic 12-oz. cans, Commercial Pack *A* (pork) | 3 | 59.1–61.8 | 60.0 | 11.5–13.5 | 12.6 |
| 4. Domestic 12-oz. cans, Commercial Pack *B* (pork) | 3 | 55.4–58.9 | 57.3 | 8.1–10.7 | 9.6 |
| 5. Domestic 12-oz. cans, Commercial Pack *C* (pork) | 3 | 57.6–58.2 | 58.0 | 9.8–10.5 | 10.1 |
| 6. Domestic 12-oz. cans, Commercial Pack *D* (ham) | 3 | 56.7–57.7 | 57.1 | 8.4–11.4 | 9.6 |
| 7. Export 6-lb. pack, canned raw pork before retorting, Series I, II, III | 15 | 63.1–66.1 | 64.8 | 18.3–24.6 | 20.7 |
| 8. Export 6-lb. pack, canned pork after retorting, Series I, II, III | 15 | 62.6–65.7 | 64.2 | 7.5–12.6 | 9.8 |

Preliminary studies showed that there was little difference in the initial vitamin $B_1$ content of canned pork and ham of this type, and that there was a similar destruction of vitamin $B_1$ during processing; both findings are in agreement with results from other laboratories (3, 5). The investigation was therefore confined to canned pork as being representative of canned spiced luncheon meat.

## Methods of Analysis

The contents of each lot or can of meat were treated as a separate entity; vitamin $B_1$ and moisture determinations were made jointly on the meat from each can. The lots of raw chop and loin meat were first ground through a 3/16 in. plate, and then mixed thoroughly before sampling. The raw meat from each can was mixed on a double-arm mixing device of standard design whereas retorted or cooked product was first ground and the total contents of the can then mixed before samples were taken.

Moisture determinations were made on samples placed in an air-oven at 98° C. for 24 hr.

Vitamin $B_1$ determinations were made by a modification of the chemical method of Jansen (2), involving the measurement of extracted thiamin as thiochrome in a photoelectric fluorometer. The sample, in each case, was incubated with pepsin and takadiastase to liberate the combined form of thiamin. It was found advantageous to buffer the extract at pH 2.0 for

the pepsin incubation (Buffer No. 1)[1], and at pH 4.5 for the takadiastase incubation (Buffer No. 2)[2].

Details of the method follow: each sample consisted of 100 gm. of meat, which was mixed with 100 ml. of distilled water on a Waring Blender to give a material of homogeneous consistency; the sample taken for vitamin $B_1$ analysis consisted of 5 to 10 gm. of blended material, which was accurately weighed into a 250 ml. centrifuge bottle. To the sample in the centrifuge bottle was first added 50 ml. of 0.2% pepsin in 0.33% hydrochloric acid; the pH was adjusted to 2.0 using 0.04% Thymol Blue as an external indicator, 2 ml. of Buffer No. 1 was added, and the sample was then incubated and extracted for one hour. Incubation and extraction were combined by turning the stoppered centrifuge bottle end over end at a speed of 29 r.p.m. in a constant temperature oven maintained at 37° C. The centrifuge bottle was removed from the extraction apparatus, the pH was adjusted to 4.5 using Brom Cresol Green as an external indicator, 2 ml. of Buffer No. 2 was added, and the sample further incubated and extracted for one hour at 37° C. This method was found to give maximum values for free and combined vitamin $B_1$ with the meat samples assayed; longer times of incubation and extraction gave no higher results. After extraction the sample was filtered to give a clear extract for the determination of thiamin. A standard procedure, using 1 or 2 ml. of this extract, made possible the conversion of thiamin to thiochrome (4); all measurements of fluorescence were made with a photoelectric fluorometer of commercial design.

## Experimental

To ascertain the precision of the method of analysis and the sampling error, duplicate analyses were carried out on two 100-gm. samples drawn from each pack of a series of seven 6-lb. cans of raw meat and three 6-lb. cans of cooked

TABLE II

ANALYSIS OF VARIANCE OF SAMPLING DIFFERENCES IN VITAMIN $B_1$ DETERMINATIONS

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Between cans | 7 | 20,852 |
| Within cans | 10 | 16,910 |
| Duplicate error | 20 | 11,264 |

meat. A statistical analysis of the results showed that the degree of variation between duplicate packs and between samples from the same pack was of the same order of magnitude, and was not significant in either case (Table II).

[1] *Buffer No. 1 : 10 ml. N hydrochloric acid and 50 ml. N potassium chloride in 1. l. distilled water.*

[2] *Buffer No. 2 : 500 ml. M potassium acid phthalate and 9.8 ml. N sodium hydroxide in 1 l. distilled water.*

It was therefore considered that a single 100-gm. sample might be used as representative of lots or cans of meat by the method of sampling used.

The samples of raw chop meat, and the domestic 12-oz. cans were purchased in retail stores. The export 6-lb. packs were obtained from a commercial establishment, and were shipped to the laboratory as canned meat that had been completely packed but not cooked or commercially sterilized, i.e. raw canned meat. Three series, each consisting of 15 cans chosen as representative of three separate batches at the canning establishment, were obtained. The series were divided at random, each into three sets of five cans. One set of five cans from each series was analysed to represent raw meat as received.

One set of five cans from each series was retorted for 200 min. at a retort temperature of 230° F., and subsequently assayed for vitamin $B_1$. This process is the one most commonly used in industry for the cooking and commercial sterilization of canned spiced luncheon meat in 6-lb. containers. This heat treatment is equivalent to autoclaving the product within the cans, and might be expected to cause considerable destruction of vitamin $B_1$. Temperature gradations within the pack followed the usual course. At the end of 200 min. at 230° F., the centres of the cans had attained 222° F. Cold water was then run through the retort until the centres of the cans reached 100° F., a process that took 75 min. These time–temperature conditions approximate commercial practice.

Five cans from each of the three series were taken for a study of the destruction of synthetic vitamin $B_1$ added as thiamin hydrochloride crystals. Each original can was opened and the contents emptied and mixed by means of a mechanical double-arm device. Vitamin $B_1$ was added as synthetic crystals dissolved in 100 ml. of distilled water to the total contents of each pack. This addition was mixed thoroughly with the meat, and the product repacked and vacuum sealed in new cans. The repacked cans were then retorted for 200 min. at a retort temperature of 230° F. and cooled in running water. Synthetic vitamin $B_1$ was added at levels of 20 mg., 100 mg., and 200 mg. per 6-lb. pack, to cans that were distributed through the three series so that all levels of original, naturally occurring vitamin $B_1$ were represented.

## Discussion of Results

Table I summarizes the analytical data obtained on raw and canned pork meat. Since raw chop meat samples (1 and 2) were different from the cuts used in canning, and were trimmed entirely free of fat and not mixed with any other ingredients, the analyses given cannot be compared directly with the amount of vitamin $B_1$ in canned product. They do, however, agree with published data on the thiamin content of raw lean pork (1, 3, 5). Little difference is shown between the vitamin $B_1$ values of the domestic 12-oz. packs of pork and ham and the export 6-lb. packs analysed; therefore both may be considered a good source of this factor.

The apparent destruction of vitamin $B_1$ during the retorting process for the 6-lb. packs is shown by Table III. The analyses given are values for the

amount of thiamin in meat from the cans of non-retorted and retorted product. The percentage destruction was calculated from these data, but it was not possible to obtain analyses on the product from the same can before and after retorting, since this would have involved changing the product by mixing and repacking. Previous experiments demonstrated that mixing and repacking, besides causing aeration of the meat, always resulted in excessive liquid rendering during subsequent retorting.

TABLE III

VITAMIN $B_1$ REMAINING IN CANNED SPICED PORK AFTER COMMERCIAL STERILIZATION

| Description of sample | Vitamin $B_1$, μgm./gm. (moisture-free basis) | | | |
|---|---|---|---|---|
| | Series I | Series II | Series III | Series I, II, III |
| 1. Average vitamin $B_1$ content of 6-lb. packs before retorting | 19.2 (18.3–20.0) | 23.6 (20.6–24.6) | 20.3 (18.9–22.1) | 20.7 (18.3–24.6) |
| 2. Average vitamin $B_1$ content of 6-lb. packs after retorting | 8.6 (7.5–10.8) | 10.5 (8.7–11.7) | 11.8 (11.1–12.6) | 9.8 (7.5–12.6) |
| 3. Calculated loss of vitamin $B_1$ during the retorting process, % | 55.3 | 55.6 | 41.9 | 52.7 |

In the product to which synthetic thiamin was added, it was necessary to repack. The results given in Table IV are, therefore, for packs that are not identical with commercial product. However, since the effect of aeration and rendering would be to increase the destruction of vitamin $B_1$, the conditions of processing are no less severe for repacked cans. If synthetic additions

TABLE IV

VITAMIN $B_1$ IN CANNED PORK (MOISTURE-FREE BASIS) AFTER ADDITION OF SYNTHETIC VITAMIN $B_1$

| Description of sample | Vitamin $B_1$, μgm./gm. | | Indicated total loss of vitamin $B_1$, % |
|---|---|---|---|
| | Before retorting | After retorting | |
| 1. Export 6-lb. packs as received | 20.7 (18.3–24.6) | 9.8 (7.5–12.6) | 52.7 |
| 2. Export 6-lb. packs with addition of synthetic thiamin at a level of 20.5 μgm./gm. (20 mgm./pack) | 41.2* (38.8–45.1) | 26.7 (25.4–29.6) | 35.2 |
| 3. Export 6-lb. packs with addition of synthetic thiamin at a level of 102.8 μgm./gm. (100 mgm./pack) | 123.5* (121.1–127.4) | 72.4 (68.4–76.6) | 42.4 |
| 4. Export 6-lb. packs with addition of synthetic thiamin at a level of 205.6 μgm./gm. (200 mgm./pack) | 226.3* (223.9–230.2) | 136.4 (130.7–141.2) | 39.8 |

* *Calculated values.*

were to be made in commercial practice, the appropriate stage would be during the mixing of the ingredients for the canned luncheon meat, and hence addition would result in no change of processing or appearance of the final commodity. The results given in Table IV indicate that an appreciable amount of synthetic thiamin was retained after the processing procedure used.

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# DRIED WHOLE EGG POWDER

## V. DEFINITION AND PROPERTIES OF LOW GRADE EGG POWDERS[1]

By M. W. Thistle[2], Margaret Reid[2], and N. E. Gibbons[3]


## Abstract

The point at which 50% of tasters regarded dried whole egg preparations as unsuitable for human consumption coincided with a rating of 2.7 on a scale ranging from 10 for excellent, fresh egg to 0 for repulsive material. The protein fraction of these low grade samples had deteriorated badly, as shown by fluorescence measurements. The fat fraction showed no evidence of peroxide oxygen formation.


## Introduction

Hitherto, information with respect to the level of quality at which trained tasters consider dried whole egg powder to be unsuitable for human consumption has been rather meagre. It was observed from time to time that taster scores were more variable on low than on high quality powders, and therefore, in order to operate at these low quality levels, highly trained tasters were required. The presence of an experienced taste panel in these laboratories made possible the present investigation.

## Materials and Methods

Ten samples were obtained which, on the basis of their storage history, could be expected to receive scores between 5 and 0 on the taste scale used (2, 3). Five of these samples consisted of powders produced in 1939 and 1940, and since stored in cardboard containers at room temperature; two powders had received harsh storage treatment (47.8° C. for five weeks); three powders had been stored at 36.7° C. for three months, and subsequently for a year at room temperature in cardboard containers.

The method of preparing the samples has been described (2). The scoring system ranged from 10 for excellent, fresh egg to 0 for repulsive material. The taste panel consisted of four tasters selected from the larger panel used in previous work (2, 3): this selected panel had 14 months' experience in quality control work prior to the present investigation. The 10 samples were scored by the panel described, with each taster also noting whether he considered the samples edible or inedible. The whole procedure was repeated a day later, with the samples in different order. Unfortunately one of the tasters revolted, so that most samples received seven judgments rather than eight; however, all data obtained were used in computing the results.

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Deterioration of the protein fraction was assessed by fluorescence values (1, 2, 3); and deterioration of the fat fraction was assessed by peroxide oxygen determinations (4).

## Results

The results are shown in Table I. Repeating the experiment provided a basis for estimating panel error; the standard error for any one sample in this instance was 0.65 palatability units, as compared with a standard error of 0.28 units at the higher quality levels. This confirms the previous observation that taster scores were more variable on poor than on good quality powders.

TABLE I

RELATION OF TASTER SCORE TO "INEDIBILITY"

| Description of sample | Average score, 1st day | Average score, 2nd day | Final score | Inedibility ratings, % |
|---|---|---|---|---|
| Three years old | 4.0 | 4.0 | 4.0 | 0 |
| Three years old | 3.3 | 3.8 | 3.6 | 14 |
| Four years old | 2.7 | 3.5 | 3.1 | 57 |
| Three years old, dried from Grade *C* eggs | 2.3 | 3.5 | 3.0 | 57 |
| Stored at 47.8° C. for five weeks, 2.3% moisture content | 2.8 | 3.1 | 2.9 | 12 |
| Canned in $CO_2$, stored at 36.7° C. for three months, one year since treatment | 3.7 | 2.0 | 2.7 | 43 |
| Canned in air, stored at 36.7° C. for three months, one year since treatment | 2.3 | 2.0 | 2.1 | 57 |
| Open pack, stored at 36.7° C. for three months, one year since treatment | 2.3 | 2.0 | 2.1 | 100 |
| Stored at 47.8° C. for five weeks, 4.5% moisture content | 2.5 | 1.5 | 2.0 | 62 |
| Dust-collector powder, three years old | 0.7 | 2.0 | 1.4 | 100 |

On the basis of the seven (or eight) judgments available for each sample, 100% considered the sample rated 4.0 as edible, while 100% considered the sample rated 1.4 as inedible. The remaining eight samples received intermediate taster scores, and with one exception, intermediate edibility ratings.

A correlation of $-.82^{**}$ was observed between "percentage inedibility" ratings and taster score. This relationship is shown graphically in Fig. 1. The point at which 50% of the tasters considered a sample to be unsuitable for human consumption coincides with a taster score of 2.7 (computed, $y = -34x + 142$).

Fluorescence measurements on these particular powders were unusually difficult to make. Certain of the defatted powders did not disperse properly in the protein solvent, but formed small balls of dry powder, the surfaces only coming in contact with the solvent. This was true of powders that had been held in cardboard containers at room temperature for a year or longer; the remaining powders behaved normally. However, the fluorescence values

** *Exceeds the 1% level of statistical significance.*

obtained all showed marked deterioration in the protein fraction; the average over the 10 samples was 130 photofluorometer units, corresponding to the average taster score of 2.69.

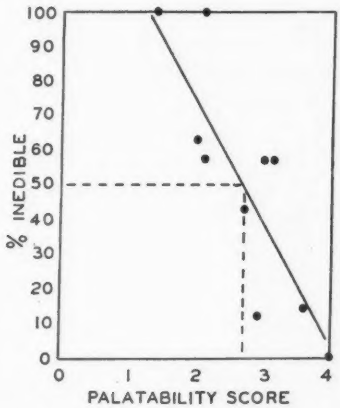


FIG. 1. *Relation of "percentage inedibility" ratings to taster score.*

It has previously been noted that considerable deterioration occurred in flavour quality without any change being detected by peroxide oxygen measurements (2). Badly deteriorated as these powders were, no evidence could be obtained of any trace of peroxide oxygen formation. Dried egg powder therefore appears to differ somewhat from other high-fat foods, as far as the behaviour of the fat fraction is concerned. This point is receiving some attention.

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